ASSESSMENT OF WATER RESOURCES MANAGEMENT ALTERNATIVES

Cape Cod National Seashore

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ASSESSMENT OF WATER RESOURCES MANAGEMENT ALTERNATIVES FOR CAPE COD NATIONAL SEASHORE

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How dead the globe would seem...

if it were not for these

surfaces!

Thoreau

PREFACE

This Assessment of Water Resources Management Alternatives is a part of the National Park Service's planning process designed to produce a Water Resources Management Plan for Cape Cod National Seashore. The Assessment is written in order to encourage public review and to clarify the management perspectives for Cape Cod National Seashore. We recognize that the management objectives of the National Park Service may, in some cases, not completely coincide with the objectives of all other Cape groups and citizens. However, we also believe there are many common objectives for the preservation of the outer Cape's water resources. We hope this document will contribute to information on the water resources of the outer Cape and encourage communication and action on water resources protection among concerned citizens and at all levels of government.

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SUMMARY

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I. INTRODUCTION

Cape Cod, with its diverse natural ecosystems and cultural heritage, is ecologically fragile and vulnerable to threats from population growth and development. The water resources on the outer Cape are particularly vulnerable to degradation. As part of the effort to protect the water resources, the National Park Service is developing a Water Resources Management Plan for Cape Cod National Seashore. This Assessment is part of the preparation of the Plan.

The purpose of the Plan is to define management actions for the protection and compatible use of the park water resources. Selection of a particular management program depends on scientific research, management experience, and public comments received during evaluation of various management alternatives.

II. NATIONAL PARK SERVICE POLICIES AND JURISDICTION

There are broad management policies and a general philosophy that guides management of national parks. Preservation and compatible use of a park's natural and cultural resources are the primary purposes of national parks and require long-term planning.

Integration with the surrounding communities is an asset to a national park, yet may render parks vulnerable to pressure for development or resource use. Conflicts are addressed during the development of park management programs.

The objectives of water resources management for the Seashore reflect the significance of these resources for both natural and human communities.

With the establishment of the Seashore, the National Park Service was given responsibility for management of the park area. However, the park's legislation as well as other state and federal laws grant certain resource management responsibilities to other agencies. The network of management may create the need for cooperative management programs.

III. WATER RESOURCES

Water Resources Description

Water is a unique chemical substance, and is necessary for many life processes. Water plays an important role in ecosystems. The freshwater aquifer provides the only source of drinking water on the outer Cape. For this plan, a water resource is defined as a body of water that exists for at least part of the year. The water resources are classified into three major types: freshwater, saltwater and floodplains.

The wide diversity of water resources and associated biological communities are a result of the Cape's geological history as well as environmental forces that continue to shape the area. The wide variety of water resources are interconnected parts of a water cycle.

Brief descriptions of each water resource are presented.

Present Status of Water Resources

The rapid population growth and the increase in tourism on the Cape since the mid-1900's, have created changes in land and resource use that can impact water resources. Park-related activities (such as recreation), land use on areas adjacent to the park or on non-federal land within the park boundary, can adversely impact water resources.

what kind of resources? have they impacted water resources? Meaning?

The vulnerabilities and the human uses and benefits from each water resource type are identified. National Park Service policies emphasize the inherent water needs of ecosystems for their preservation.

Water Quality

There are state water quality standards for surface waters, but not for groundwater. All surface waters in and adjacent to the Seashore are designated National Resource Waters, the highest state protection category. Coastal waters off Cape Cod are also designated as an ocean sanctuary.

There are no known violations of water quality standards in the fresh surface waters in the park. However, certain kettle ponds, Pilgrim Lake, and the Herring and Pamet Rivers have some water quality problems.

outside park?

The groundwater on Cape Cod is generally of high quality. The most frequently encountered problems are elevated concentrations of salt, nitrogen (as nitrate), iron and manganese.

There are no known violations of water quality standards for coastal waters within the Seashore. However, there are some water quality problems adjacent to the park boundary in Provincetown and Wellfleet Harbors.

III. (continued)

Since 1972, there have been annual closures of shellfish harvesting due to red tide in certain locations in Eastham and Orleans.

Twice during the last three years, oil from cargo vessels has washed up on the shores of the outer Cape.

<u>Water Quantity</u>

Precipitation on the outer Cape averages 40 inches per year and evapotranspiration is estimated to be 25-26 inches per year. Annual recharge is estimated to be 17-18 inches per year and sustains the freshwater aquifer.

<u>Floodplain Management and Wetland Protection</u>

The 100-year floodplain and wetland areas within the Seashore are mapped and the National Park Service-managed structures and facilities located within these areas are identified.

<u>Water Resources Monitoring</u>

Monitoring water quality and quantity is performed by a number of organizations.

IV. WATER RESOURCES PROBLEMS AND ASSESSMENT OF PROPOSED MANAGEMENT ALTERNATIVES

1. Management of Groundwater Quantity

Park Service policies and legal constraints on removal and consumptive use of resources, and the outer Cape's water resource limitations, create a potential conflict with the increased demand for use of groundwater resources.

Alternatives for Management

1. No additional management action.

Preferred Alternative: 2. Develop a comprehensive Public Information and Water Conservation Program for Cape Cod National Seashore.

Research proposed.

2. Management of Groundwater Quality

Groundwater quality is threatened by certain activities and land use within and adjacent to the Seashore.

Alternatives for Management:

1. No additional management action.

2. Develop a Groundwater Quality Program for Cape Cod National Seashore.

Preferred Alternative: 3. Develop a Cooperative Groundwater Quality Program with adjacent towns.

No research proposed.

3. Management of Freshwater Kettle Ponds

Research on the kettle ponds indicate current and potential water quality problems.

Alternatives for Management:

1. No additional management action.

2. NPS Pond-Specific Management Plans.

Preferred Alternative: 3. NPS Cooperative Pond-Specific Management Plans.

Continuation of current research.

4. Management of Gull Pond Sluiceway

Maintenance of the Sluiceway to allow passage of herring into Gull Pond is manipulation of the environment in order to retard a natural shoreline deposition process, and may not be consistent with National Park Service policies.

Alternatives for management:

1. No additional management action.

Preferred Alternative: 2. Maintain an open sluiceway.

5. Management of Pilgrim Lake

There are water quality problems in Pilgrim Lake. The eutrophic conditions, consistent blue-green algae blooms and periodic population outbreaks of midges, are influenced by activities on land around the lake and by the lake level structures.

Alternatives for management:

1. No additional management action.

Preferred alternative: 2. Develop a Management Plan and Cooperative Management Agreement for Pilgrim Lake

Research proposed.

6. Management of the Water and Marsh Areas Upstream from the Herring River dike.

   The repair of the Herring River dike in 1974 altered the pattern of tidal flow to the marsh areas behind the dike and thus changed the biological community. There is an active program of mosquito control ditching in the marsh that may adversely impact the ecology of the marsh.

   Alternatives for Management:

   1. No additional management action.

   Preferred alternative: 2. Develop a Management Program for the Herring River and associated marsh ecosystems.

   Research proposed.

7. Assessment and Management of the Impacts of Acid Rain

   The ecological communities within the Seashore may be adversely affected by acid rain.

   Alternatives for Management:

   No direct management actions are are proposed.

   Research proposed.

I. Introduction

Cape Cod, a 70-mile peninsula of glacial origin, is an area of outstanding beauty and historic significance. Diverse natural ecosystems - beaches, dunes, ponds, wetlands and forests - as well as historic areas and a cultural heritage, are all part of the Cape's resources. Recognition of the national significance this unique outer Cape coastal area led to the establishment of Cape Cod National Seashore in 1961.

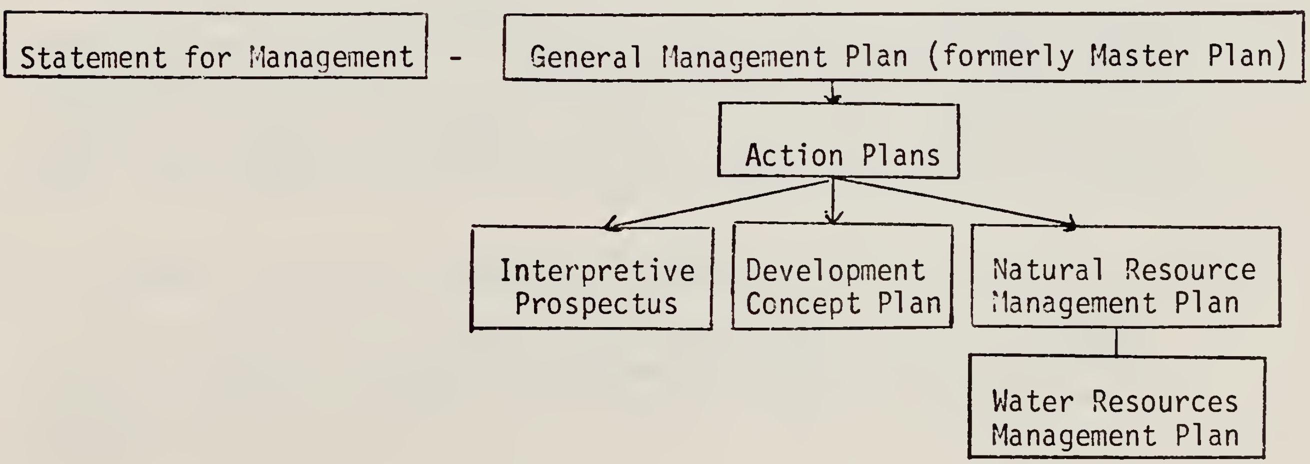
Cape Cod National Seashore is located within a days drive of approximately one-third of the U.S. population. The beauty of the Cape attracts an increasing number of visitors every year; in 1978, over 5 million people visited the Seashore. In addition, the year-round and seasonal population on the Cape has increased dramatically in the past 25 years and is projected to continue to increase. Such rapid growth, development, and resource use can seriously threaten environmental quality in an ecologically fragile area such as Cape Cod.

The water resources on the outer Cape are particularly vulnerable to degradation. During the last decade, there has been increasing evidence of both current and potential water resource problems and the associated adverse ecological and economic impacts. As part of the local, regional, and national efforts to respond to these problems and protect water resources, the National Park Service is developing a Water Resources Management Plan for Cape Cod National Seashore.

A. Background on National Park Management Plans

To achieve the legislated dual goals of resource preservation and compatible use, the National Park Service performs a variety of management activities including resource protection and management, environmental interpretation and education, and park administration. Park management is guided by the National Park Service policies and the legislation for each park, which are implemented through park plans (see Figure 1).

Figure 1. Planning Documents for National Parks



The Water Resources Management Plan is a section of Phase II ~~part~~ of the Natural Resources Management Plan for Cape Cod National Seashore. Phase I of a Natural Resources Management Plan for Cape Cod National Seashore has been completed (Godfrey *et al.*, 1977). Phase I gives a general description of the ecosystems and physiography of Cape Cod National Seashore, lists potential management problems, the possible management actions and the scientific research needed to suggest management solutions or assess the consequences of proposed management actions. Phase II of the Natural Resources Management Plan, using Phase I as a foundation, will address specific resource issues in the park and determine management strategies to deal with resource-related problems.

~~The Water Resources Management Plan is a section of Phase II of the Natural Resources Management Plan for Cape Cod National Seashore.~~ ~~Water resources were given priority in the process of resource management planning in response to an agreement~~ between the Environmental Protection Agency and the Department of the Interior. ~~The 1977 Amendments to~~ the Federal ~~Clean Water~~ Act ~~were~~ was the impetus for this agreement which calls for direct involvement of the National Park Service in the national efforts to maintain or enhance the quality of water resources through preparation of Water ~~Resources~~ Quality Management Plans ~~for national parks~~.

B. Study Area

The study area for the Water Resources Management Plan is the land and water within the legislated boundaries of Cape Cod National Seashore (see Figure 2). The Seashore boundaries include approximately 44,600 acres; 16,900 acres of this land is under water. The National Park Service currently manages 26,031 acres, however, some of the land area within the boundaries will continue in non-federal (either Commonwealth of Massachusetts, town or private) ownership indefinitely. The major part of the federally-owned Park Service land area remains in a natural, undeveloped state. In this report, the area between Provincetown and Chatham is referred to as the outer Cape.

Cape Cod National Seashore has a wide variety of fresh and salt water resources that were formed by the geological events which created the land mass of Cape Cod. The diverse water resources - coastal and freshwater wetlands, bogs, kettle ponds, dune ponds, estuaries, and groundwater aquifer sub-basins, are all interrelated to each other and each is an integral part of the ecology, history and beauty of Cape Cod.

C. Purpose of the Water Resources Management Plan

The purpose of the Water Resources Management Plan for Cape Cod National Seashore is to define management action for the protection, conservation and compatible use of the park water resources. Specific purposes are:

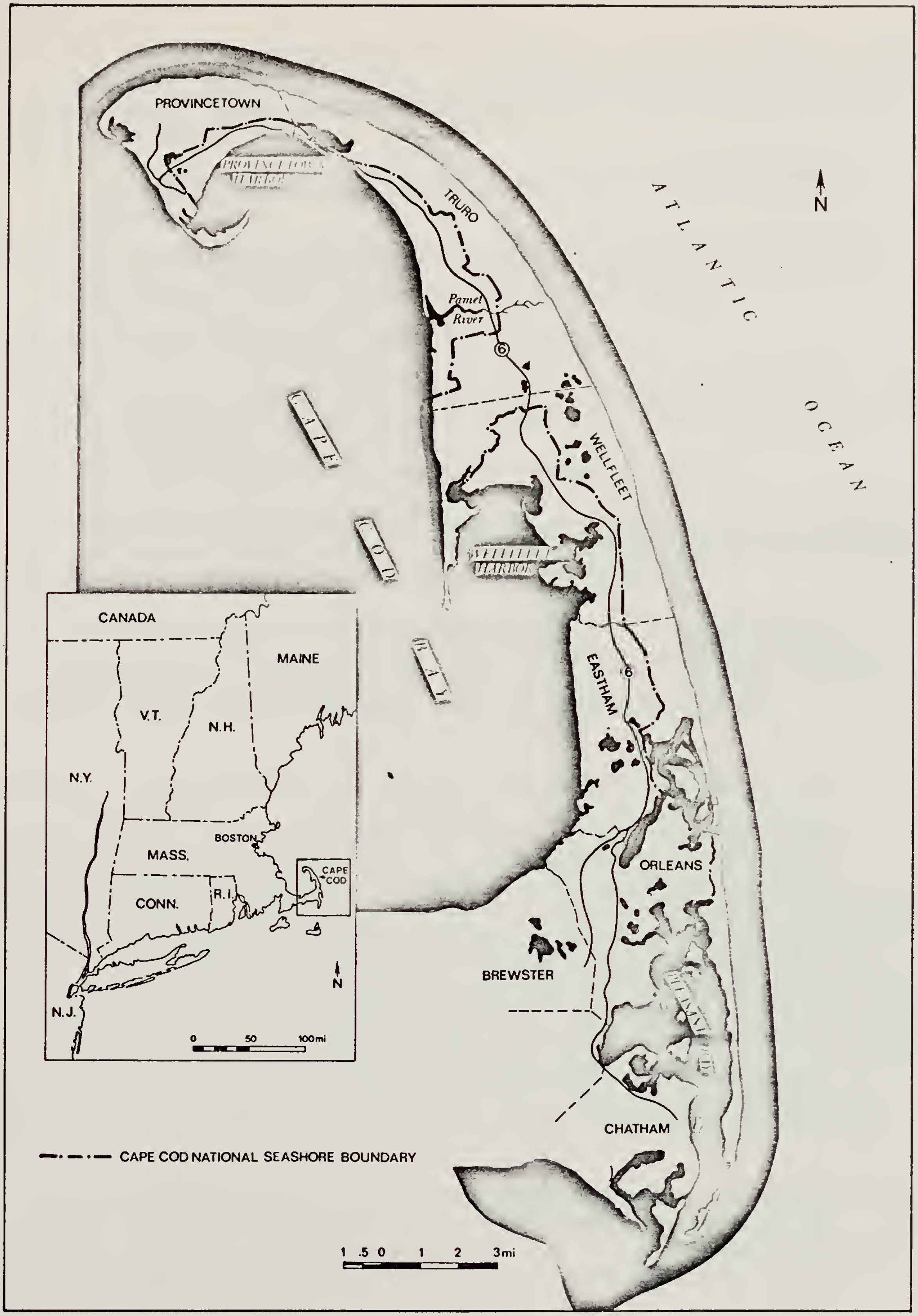


Figure 2 Regional Location and Boundary of Cape Cod National Seashore.

1. To provide a concise source of information and references on the Seashore's water resources, including an inventory of the present human uses of these resources and identification of vulnerabilities of each resource type.

2. To identify current and potential water resources management problems.

3. To identify and assess water resources management alternatives and develop a water resources management program.

4. To identify additional research needed to:

   a) develop successful water resources management programs;
   b) assess impacts of proposed activities which may affect the water resources; and
   c) assess impacts of proposed management programs.

5. To clarify the legislative mandates of the National Park Service in terms of water resources management and the planning procedures to the local communities, and the surrounding region.

6. To improve and encourage communication with the appropriate agencies of the Commonwealth of Massachusetts, the surrounding region, and, in particular, the towns adjacent to the Seashore, in order to encourage coordinated water resources management.

D. Steps in the Development of the Water Resources Management Plan

The overall planning process is similar for all park management plans. Selection of a particular plan or management program depends heavily on scientific research, management experience, and on public comments received during the evaluation of various management alternatives. The National Park Service Regional Science Program provides part of the scientific data needed for management decisions, but also coordinates studies with other research agencies and institutions. Management experience is also a valuable source of information on management alternatives, the potential impact, and the practical viability of a particular management action. Public participation is another important part in the development of a plan, providing valuable exchange of information and coordination with resource management in areas adjacent to the National Seashore.

The specific planning steps for the Water Resources Management Plan are listed in Table I. Although this list presents the most direct sequence of steps, the planning process is flexible and can incorporate any changes deemed necessary during the process of plan development.

Table I. Steps for the Water Resources Management Plan

		Completion Dates
Step 1	Public notice of the preparation of a Water Resources Management Plan	1979
Step 2	Preparation of an Assessment of Water Resources Management Alternatives	1980
Step 3	60-day Public Review of the Assessment	
Step 4	Preparation of a Draft Water Resources Management Plan (The Draft Plan will contain the water resources management alternatives selected by the National Park Service after consideration of the public comments.)	
Step 5	30-day Public Review of the Draft Water Resources Management Plan	
Step 6	Preparation of a Final Water Resources Management Plan	
Step 7	30-day Public Review of the Final Water Resources Management Plan	
Step 8	Plan Implementation by the National Park Service, Cape Cod National Seashore.	

The initial public announcement (Step 1) was accomplished by a letter and a press release (see Appendix A and B). The letter introduced the Water Resources Management Plan and requested public comments on the accompanying preliminary outline and list of water resources problems.

This report, the Assessment of Water Resources Management Alternatives, represents Step 2 in the preparation of the Water Resources Management Plan. The Assessment contains two major sections: a brief description of the Seashore's water resources, and a section which develops and assesses management actions for the water resources problems identified. This Assessment of Water Resources Management Alternatives will be available for public comment for 60 days from the date of distribution. The Assessment plus an evaluation of all public comments received will form the basis for selection of particular water resources management alternatives. The management actions selected will then be published as the Draft Water Resources Management Plan that will be available for public comment for 30 days. After this period, all public comments received will be considered, and a Final Water Resources Management Plan will be prepared. Notice of the availability of the Final Plan for a 30-day period of public review will be

published in the Federal Register. After 30 days, the Plan will be implemented.

II. NATIONAL PARK SERVICE MANAGEMENT POLICIES AND JURISDICTION

A. National Park Service Management Policies

Preservation of the "best of our land" in our National Parks signifies the value we place on our natural, cultural and historic heritage. Today the National Park Service faces the challenge of protecting this heritage by managing a diverse system of parks. National parks represent a continuum from urban recreational and historic areas to the wilderness lands of Alaska, with many parks such as Cape Cod National Seashore somewhere between these extremes.

Management objectives are specific for each park area and in some cases, may be specific for different acreage within a park (National Park Service, 1978). The objectives are determined in part by the legislation establishing a park and reflected in subsequent National Park Service plans. Yet there are broad policies and a general philosophy that guides the management of all areas of the National Park system stemming from the legislation establishing the Park Service (see Appendix C) (National Park Service Organic Act, 1916, 39 Stat. 535). According to this legislation, National Parks are established in order to

> "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (39 Stat. 535).

In 1978, Congress reaffirmed this purpose:

> "The authorization of activities [in National Parks] shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these areas have been established..." (P.L. 95-250, 92 Stat. 166)

Preservation of natural and cultural resources requires a long-term perspective ~~in order~~ to protect the ecological integrity of the area as well as to maintain the historic setting and cultural resources. Management decisions on the extent and nature of proposed uses and development activities within a national park are based on this general management philosophy and the park-specific management objectives.

For management of park areas, preservation of entire ecosystems and not simply specific biological or historic features is a significant aspect of Park Service policy. Preserving ecological integrity is particularly important since natural ecosystems require a certain, often unknown, level of "intactness". Since ecosystems are the functional units of nature, successful management must maintain the integrity of those systems, and seek to avoid alteration or interferences with natural ecosystem processes that perpetuate these systems. Ecosystems are also dynamic, so it is necessary to recognize this inherent characteristic in management goals, as well as in the management process. Assuring the unimpaired operation of ecosystems, while providing a compatible level of human use, represents a park management approach that is sometimes unpopular yet pragmatic and economical in the long run.

Management requires an understanding of the ecosystems in an area and the relationship between the natural environment and the cultural resources. This understanding is achieved through management experience and through scientific research in natural and social sciences. The National Park Service, through its Science Program obtains information for management from its own scientists and by contracting with other agencies, academic institutions (through cooperative research programs), and private consulting firms. The research is designed to provide the specific information necessary for evaluating current or potential resource problems and for developing viable resource management programs.

In many ways, parks are islands set aside from the demands, exploitation, and adverse pressures of an increasingly urban society. Yet parks still remain an integral part of the fabric of the surrounding region, ecologically as well as culturally. Integration with the surrounding communities is an asset to the National Parks system yet simultaneously may render park areas vulnerable to pressure for development or resource use. Adjacent communities also obtain many potential benefits (e.g., increased tourism, open space preservation, and watershed protection) from geographic association with a national park, as well as certain problems (such as those associated with the tourist industry), and certain restrictions. In particular, those land uses whose influences extend across park boundaries, adversely impact the park's resources, are then incompatible with resources management. Such conflicts are addressed during the development of park management programs.

Today, many national parks are threatened by impacts whose source is outside park boundaries and park jurisdiction (National Park Service, 1980). Consequently, protection of national parks can be most successfully accomplished with the support of the neighboring communities and the rest of the American public. In the words of Newton Drury, an earlier National Park Service Director:

> "if we are going to succeed in preserving the greatness of the National Parks, they must be held inviolate... If we are going to whittle

away at them we should recognize at the very beginning, that all such whittlings are cumulative and that the end result will be mediocrity in the long-term protection of our national parks. Greatness will be gone."

B. Management Goals and Objectives for Cape Cod National Seashore

The legislation establishing Cape Cod National Seashore in 1961 (P.L. 87-126, 75 Stat. 284), specifies preservation as the primary goal:

> *"In order that the Seashore shall be permanently preserved in its present state, no development or plan for the convenience of visitors shall be undertaken which would be incompatible with the preservation of the unique flora and fauna or the physiographic conditions now prevailing or with the preservation of such historic sites and structures.*

However, the legislation does allow the National Park Service to:

> *"provide for the public enjoyment and understanding of the unique natural, historic and scientific features of Cape Cod within the Seashore by establishing such trails, observation points, and exhibits and providing such services as he may deem desirable for such public enjoyment and understanding...* [and] *may develop for appropriate public uses such portions of the Seashore as he deems especially adaptable for camping, swimming, boating, sailing, hunting, fishing, the appreciation of historic sites and structures and natural features of Cape Cod and other activities of similar nature."*

The variety of water resources is a significant part of the beauty of Cape Cod and has influenced the history of the area as well as the cultural traditions. Water is also an integral component of all ecosystems and thus preservation of this resource plays an important role in preserving the ecological integrity of the area. The objectives for water resources management reflect the significance of these resources, as well as their interrelatedness in the total network of natural and human systems.

The Park Service Management Policies and the specific legislated goals for Cape Cod National Seashore lead to the following water resources management objectives:

1. To protect the natural processes of the water cycle from disturbance and thus preserve the diverse ecological systems dependent on natural water levels and water quality.

2. To maintain or restore the quality of water resources through resources management actions and through cooperation with local communities and regional, state or federal agencies.

3. To contribute to the scientific base for water resources management and perform or coordinate water resources research.

4. To provide environmental education and interpretation of water resources of outer Cape Cod and thus promote public awareness of the nature of water resources and an understanding of the current and potential human impacts upon these resources.

5. To promote water conservation through direct National Park Service action and through cooperation with local communities or with regional, state or federal agencies.

C. Responsibility for Water Resources Management With Cape Cod National Seashore

Many laws -- federal, state and local -- influence water resources management. This section presents a brief overview of the water resources management authority within Cape Cod National Seashore.

laws

The ~~legislation~~ establishing Cape Cod National Seashore delineates the park boundary (see Figure 2) and grants the National Park Service jurisdiction for management of the park area (with authority under the Secretary of the U.S. Department of the Interior). ~~Since the legislation specifies that certain pieces of ("improved") property will never be acquired by the National~~ Park Service, parcels of non-federal land will remain within the boundary of the Seashore. The Park Service is given the authority to regulate certain activities on these non-federal properties by zoning regulations (see Section 5 of P.L. 87-125, Appendix D). Even so, the patchwork of ownership created by the legislation does affect park management and necessitates communication and management coordination with the land holders (either private individuals, towns, or the Commonwealth of Massachusetts).

Under the conditions of the Seashore's enabling legislation as well as other state and federal laws, the Park Service shares certain park water resources management authority with other agencies.

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Cape Cod National Seashore is within the Massachusetts Coastal Zone, and all federal activities in the coastal zone must comply with the State's policies in the Coastal Zone Management (CZM) Plan. Consequently, the CZM policies are reviewed when the National Park Service formulates management programs. The Massachusetts CZM office in Boston reviews each National Park Service Plan (including the Water Resource Management Plan). If a National Park Service plan complies with the State's policies, the Massachusetts CZM office issues a "certificate of federal consistency". In addition, park Water Resources Management Plans must also be consistent with the regional

privately-owned lands in Seashore?

prepared under the aegis of

Water Resource Management Plans ~~approved by~~ the Federal Water Resource Council. ~~Massachusetts~~ is included in two regional plans by the New England River Basins Commission (NERBC, 1975 and 1978).

and amendments

Section 208 of the Federal Clean Water Act ~~of 1972 (P.L. 92-500, amending the Federal Water Pollution Control Act~~) mandated preparation of State Water Quality Management Plans. For the purpose of water planning, the Commonwealth was divided into 24 major drainage basins; Cape Cod National Seashore is located in the Cape Cod basin. In 1975, the Governor designated the Cape Cod Planning and Economic Development Commission (CCPEDC) as the agency to prepare the 208 Plan for the Cape. Subsequently, in 1978, the CCPEDC produced a Water Quality Management Plan/Environmental Impact Statement (EIS) for Cape Cod which is now in final form (CCPEDC, 1978a and 1978b). In June 1979, a Status Report for the CCPEDC district was prepared by Massachusetts Department of Environmental Quality Engineering (DEQE, 1979). The regional 208 water plan addresses primarily water quality but also discusses water supply on Cape Cod. The CCPEDC is currently working with the towns on implementation of the plan's recommendations.

In September 1978, the Massachusetts Water Resources Commission filed the State Water Quality Standards required by the Massachusetts Clean Waters Act (Mass. G.L. Chapter 21, Section 26-53) (Commonwealth of Massachusetts, Water Resources Commission, 1978). These regulations classify all the surface waters of Massachusetts and set minimum criteria for water quality. The Standards also designate all surface waters in and adjacent to Cape Cod National Seashore as Outstanding National Resource Waters (Regulation 4.4 of the Massachusetts Water Quality Standards). This designation is meant to preserve the outstanding value of these resources by prohibiting all new discharges (defined as any addition ~~of~~ a pollutant). The regulation also requires the elimination of existing discharges unless alternative means of disposal are not reasonably available, or unless the discharges do not affect the quality of the water as a national resource.

In July 1978, the Massachusetts Department of Environmental Management (DEM) filed the Regulations for the Ocean Sanctuaries Act (Mass. G.L. Chapter 132, Sections 13-17) and designated the Cape Cod Ocean Sanctuary, which completely surrounds Cape Cod National Seashore. Certain activities (excavation, drilling, construction and dumping) are prohibited within the sanctuary.

The legislation establishing Cape Cod National Seashore grants certain responsibility for management of hunting, fishing and shellfishing to agencies of the Commonwealth of Massachusetts and the local Cape communities. (see Section 7(c) of P.L. 87-125 in Appendix D). Thus the Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles (including the Division of Fisheries and Game, the Division of Marine Fisheries and the Public Access Board) and the local towns share some of the responsibility for management of hunting, fishing and shellfishing within the Seashore. To promote coordinated management, representatives from the National Park Service and the Division of Fisheries and Game have signed a Cooperative Management Agreement and meet annually to discuss management of inland and marine fisheries

and wildlife within the Seashore. However, there is currently no formal agreement with any of the other State agencies or towns.

When the Commonwealth donated the Provincelands and Pilgrim Spring State Park to the National Seashore, the deeds of donation granted the Cape Cod Mosquito Control Project (under the State Reclamation Board with Massachusetts Department of Food and Agriculture) the right to control the population of certain water-dependent insects, and thus indirectly conveyed a water resources management role specifically on these lands. At present, there is no formalized communication channel between the National Park Service and the Cape Cod Mosquito Control Project to coordinate their water resources management activities.

The Massachusetts Wetlands protection Act (Mass. G.L. Chapter 131, Section 40) authorizes local Conservation Commissions to protect wetland areas as well as consider impacts on public water supplies and marine resources in their review of proposals for activity in or adjacent to a wetland area. The Wetland Restriction Acts (Mass. G.L. Chapter 131, Section 40A and Mass. G.L. Chapter 130, Section 105) allow the Commissioner of the Department of Environmental Management (DEM) to place deed restrictions on development in significant inland and coastal wetlands.

The Massachusetts Community Sanitation Program (Mass. G.L. Chapter 111, State Environmental Code, Title 5) is designed to protect water quality from degradation by subsurface waste disposal. Massachusetts Department of Environmental Quality Engineering (DEQE) and the local Boards of Health set standards and issue permits for subsurface discharge.

These laws and others not discussed in this section, influence water resources problems and management within Cape Cod National Seashore. The network of jurisdiction established by legislation may require a legal review by the National Park Service in order to identify all agencies or individuals involved prior to the selection of a particular water management alternative. The network of jurisdiction that exists at Cape Cod National Seashore may also create the need for coordinated resources management programs. (For further information on compliance with existing laws and regulations see Sections IV.B. 1-7 and Section VI.)

III. Water Resources

A. Water Resources Description

1. Significance of Water Resources

Water is a unique substance chemically. Materials necessary for life processes, such as nutrients, are continually recycled through natural systems along pathways called biogeochemical cycles. Water is the medium in which most of these chemicals flow as they recycle between organisms and the environment. Consequently, water itself plays a major ecological role.

Wetlands, in particular, play an important role in the biogeochemical cycling of nitrogen and in the process, may remove potentially harmful forms of nitrogen from the water. Other nutrients, sediment and other pollutants (e.g., trace metals) are also removed from water as it passes through wetlands.

The variety of water and water-related habitats supports a diverse group of organisms, both plant and animal, some of which are rare. Coastal and inland wetlands provide habitat for many species of birds, particularly waterfowl and shorebirds. Salt marshes and neighboring estuaries provide materials that support marine life in adjacent coastal waters. Many species of marine organisms, that are commercially valuable such as finfish, shellfish and lobster, spend part or all of their life cycle in the productive coastal marshes and estuaries. Coastal features, such as salt marshes, play a role in the impact of buffering coastal storms, since the plant stems, leaves and roots and peat layers in the salt marsh are resistant to erosion and tend to dissipate storm wave energy.

The aquifer sub-basins, not conspicuous but certainly important water resources, are the major water source for many freshwater wetlands, and for ponds, rivers and coastal estuaries. The fresh groundwater also provides the sole source of drinking water on the outer Cape.

The water resources of Cape Cod National Seashore are valuable for their beauty and the aesthetic enjoyment they provide. Millions of people travel to the Cape each year to enjoy the scenic and recreational opportunities -- many of which are closely tied to water resources. Tourism is an important component in the economy of many towns on the outer Cape.

Historically, the abundance of water resources and their apparent resiliency to disturbance has allowed an atmosphere of complacence toward protection of water quality and quantity. More recently however, with the realization of the value of water resources and knowledge that human activities can degrade or destroy the biological, recreational, and economic qualities of marine and freshwater environments, the importance of maintaining the quality and integrity of natural water systems is being recognized.

2. Definition and Classification of Water Resources

For the purpose of this plan, a water resource is defined as a body of water which exists for at least a part of the year. Floodplains are also treated as water resources even though these areas are subject only to intermittent flooding. A water resource is either fresh, brackish or marine and is either open water (flowing or standing) or covered to some extent with wetland vegetation. The existence of a variety of biological communities in close association with a water body provides a convenient label for many water resources in a resource classification system.

A variety of classification systems for water resources are available. Many systems have been developed with the increasing awareness of the value of water resources in general, and wetland areas in particular, and the resulting federal and state protective legislation. The system used here to classify the water resources is basically consistent with systems used in previous National Park Service studies and plans for Cape Cod National Seashore (Randall, 1962; Godfrey *et al.* 1977; Waggoner, 1979). Table II summarizes this classification system and Appendix E compares this system with other classification systems used previously for this area of Cape Cod. Figures 6-20 indicate the locations of the surface and groundwater resources within Cape Cod National Seashore. The boundaries of each type of resource are not distinct in all cases and may integrate into one another or into more terrestrial habitats.

Table II Classification of Water Resources of Cape Cod National Seashore for the Water Resource Management Plan

	Indicated on Water Resources Maps, Figures 5-20 as:
a. Freshwater	
1) Groundwater	Groundwater Sub-basins, Figures 6-1
2) Ponds and Lakes	Ponds and Lakes, Figures 11-15
a) Dune Ponds	
b) Kettle Ponds	
c) Coastal Ponds	
3) Streams and Rivers	Streams and Rivers, Figures 11-15
4) Freshwater Marshes	Fresh Marsh, Figures 11-15
5) Bogs	Tree/Shrub Swamp, Figures 11-15
a) *Sphagnum* Bogs	
b) Cranberry Bogs	
6) Freshwater Swamps	Tree/Shrub Swamp, Figures 11-15
a) Shrub Swamp	
b) Tree Swamp	
b. Saltwater	
1) Open Marine	
a) Shallow Coastal Waters*	
b) Estuarine**	
2) Intertidal	
a) Salt Marsh	Salt Marsh, Figures 11-15
b) Tidal Mud and Sand Flats*	
c) Rockweed - Barnacle†	
c. Floodplain	100-Year Floodplain, Figures 16-20

* Not specifically delineated on Figures 11-15. However, U.S. Geological Survey Topographic Quadrangles indicates the locations of these water resources.
** Description of locations is given in Section III.A.5. and in Massachusetts CZM Plan, Volume II.
† Description of locations is given in Section III.A.5.

3. Origin of Water Resources

This wide diversity of water resources and associated biological communities present on the Cape today are a result of the Cape's geological history as well as the environmental forces which continue to shape the area. One major geological event, the Wisconsin glaciation, created most of the land of Cape Cod and essentially set the foundation which has been continually modified during the ensuing years (Strahler, 1966 and 1972, U.S. Army Corps of Engineers, 1979; Leatherman, 1979a). Many water resources also had their origin during this glacial and post-glacial time. The Pamet and Herring Rivers follow the paths of the old glacial outwash channels. The kettle ponds of the Seashore represent holes in the outwash plain that were once filled with large blocks of glacial ice. The underlying sediments of outer Cape Cod are well-sorted glacial till (primarily sand and gravel) and form an underground fresh-water storage area (or aquifer). Salt marshes and tidal flats formed with the rising sea level associated with melting of the glaciers (Redfield, 1965 and 1972).

The diversity of water resources present is also influenced by environmental forces and by the process of ecological succession. Erosion of the eastern edge of the outer Cape by tides, winds, waves and currents have changed and continue to change the land today (US Army Corps of Engineers, 1979). With melting of glacial ice, plants began to colonize the uncovered, barren land and eventually a variety of plant and animal communities was established. As a plant community grows and changes, the particular animals and plants which live there also change in an orderly and fairly predictable pattern of ecological succession. The pattern of succession depends on a variety of environmental factors and conditions, and results in a changing complex of ecological communities on the landscape over long periods of time. Changes in community types affect, to some extent, the local water chemistry, since as the water flows through an ecosystem it carries many chemicals and materials from the surrounding organisms.

4. Interrelationships Among Water Resources

Although there are a variety of water resources, all are ultimately interconnected within the hydrologic or water cycle. All water molecules are continually moving through a global hydrologic cycle (illustrated in Figure 3). The relative amount of water present in each phase of the cycle as well as the average length of time a particular water molecule remains in each phase are also indicated in Figure 3.

The local manifestation of the hydrologic cycle can also be described for the outer Cape. The cycle is determined by the array of climatic, geologic and biological factors specific to an area. On Cape Cod, water follows a number of possible routes through the cycle (see Figure 4). Rain that falls directly on land may evaporate back into the atmosphere

Figure 3

Figure 4

or percolate through the soil zone down to the water table. Vegetation may intercept and absorb rainfall directly, or extract if from the upper soil layers. In either case, the water reenters the atmosphere through transpiration from the surface of the plant. Water also enters the atmosphere by evaporation from land and water surfaces. Since it is difficult to separate transpiration and evaporation, the total amount of water reentering the atmosphere is called evapotranspiration. The fraction of water that reaches the water table spends a great deal of time in the aquifer but eventually flows slowly as groundwater into the ocean. There is continuous leakage from each groundwater lens out into coastal waters, diluting the waters in estuaries or coastal embayments to produce a brackish environment. The wide diversity of fresh, brackish, and salt water resources on the Cape are thus intimately interconnected by this hydrologic cycle. (The local water budget is discussed quantitatively in Section III.B.5)

5. General Description of the Water Resources

The following sections give brief descriptions of each type of water resource and identify some of the locations and prime examples of each type of resource within Cape Cod National Seashore. This information provides a basis for assessing the vulnerabilities of each resource that allows identification and prediction of water resource problems (see Section III.B.2. and Section IV.). The general descriptions are intended to be brief summary statements which characterize the water resources and closely associated plant and animal communities. More detailed description of the water ecosystems and other natural and cultural resources of the Seashore can be found in other references cited in the text. The National Park Service publication entitled "The Ecology of Cape Cod National Seashore" (Godfrey *et al.*, 1978) provided the basis for many of the descriptions in this plan.

a. Freshwater Environments

Freshwater environments of Cape Cod National Seashore include surface waters, a variety of wetlands and the groundwater aquifer sub-basins; all are characterized by salinity below 0.1 part per thousand (ppt). Pilgrim Lake is brackish (with a salinity around 3-7ppt) but is described within the freshwater resources section for simplicity. The water chemistry of each resource is influenced by the source of water, which on the outer Cape is either direct precipitation or groundwater seepage (see Section III.B.4).

The majority of the Cape's surface freshwater resources are direct expressions of the water table. However, some wetlands may be underlain with an impermeable layer (such as a clay lens) and thus have an isolated water table "perched" above the normal groundwater table. The frequency of perched water tables on Cape Cod is thought to be small but no detailed studies have been made.

1) Groundwater

The outer Cape's largest body of freshwater is contained in the groundwater aruifer sub-basins (see Figure 5). Freshwater occupies the spaces between the sandy glacial material and an entire water mass (lens) actually floats on the surrounding seawater, which is heavier. On the outer Cape, either open coastal waters or saltwater in the glacial sediments surrounds the groundwater aquifer on all sides and from below. The bedrock on the outer Cape is approximately 900 feet below sea level near Provincetown (Oldale, 1969). The freshwater in the glacial sediments keeps the salt groundwater from intruding into the upper sand deposits (see Figure 5). The surface of the fresh groundwater lens is known as the water table, the sides are areas of discharge and the bottom is the fresh-saltwater transition zone. The transition zone is actually an area of mixing of fresh-and seawater. In the North Truro sub-basin, the transition zone is less than 50 feet thick (LeBlanc, USGS, written comm., 1980). As mentioned previously, the elevation of the water table does occasionally occur above the land contour, creating surface exposure of the groundwater in ponds and wetlands ecosystems. On the outer Cape, the elevation of the water table varies geographically and seasonally. (For more information on groundwater sub-basins, see Section III.B.5.)

The U.S. Geological Survey has determined that there are actually four unconnected groundwater sub-basins (that is, separate freshwater lenses) under the outer Cape (see Figure 6-10). These four separate sub-basins are divided by groundwater discharge areas in the form of streams and marshes. Under the existing hydrologic conditions, there is no groundwater flow between the basins (Guswa, USGS, written comm., 1979). However, it is possible that flow between the basins may be induced during periods of extreme disruption or stress of the hydrologic system.

Generally, the direction of groundwater flow on the outer Cape is from the central zone, where the water table is generally highest, toward either shore (see Figure 5). The pattern of flow creates circulation patterns within the basins such that the flow is not consistently downward but can be in any direction, horizontally or vertically. The paths, direction, and rate of flow in a given locality are influenced by hydraulic pressures and by the nature of the glacial sediments since certain materials, such as clay, occur sporadically and are less permeable than sand. Local patterns of flow may be approximated from the U.S. Geological Survey's groundwater contour map; however, for accuracy, local patterns must be verified with field data.

On the Cape, precipitation is the only form of recharge to the groundwater aquifer. There are seasonal as well as year-to-year variations in total precipitation. (See Section III.B.5. for information of the water budget for outer Cape Cod.)

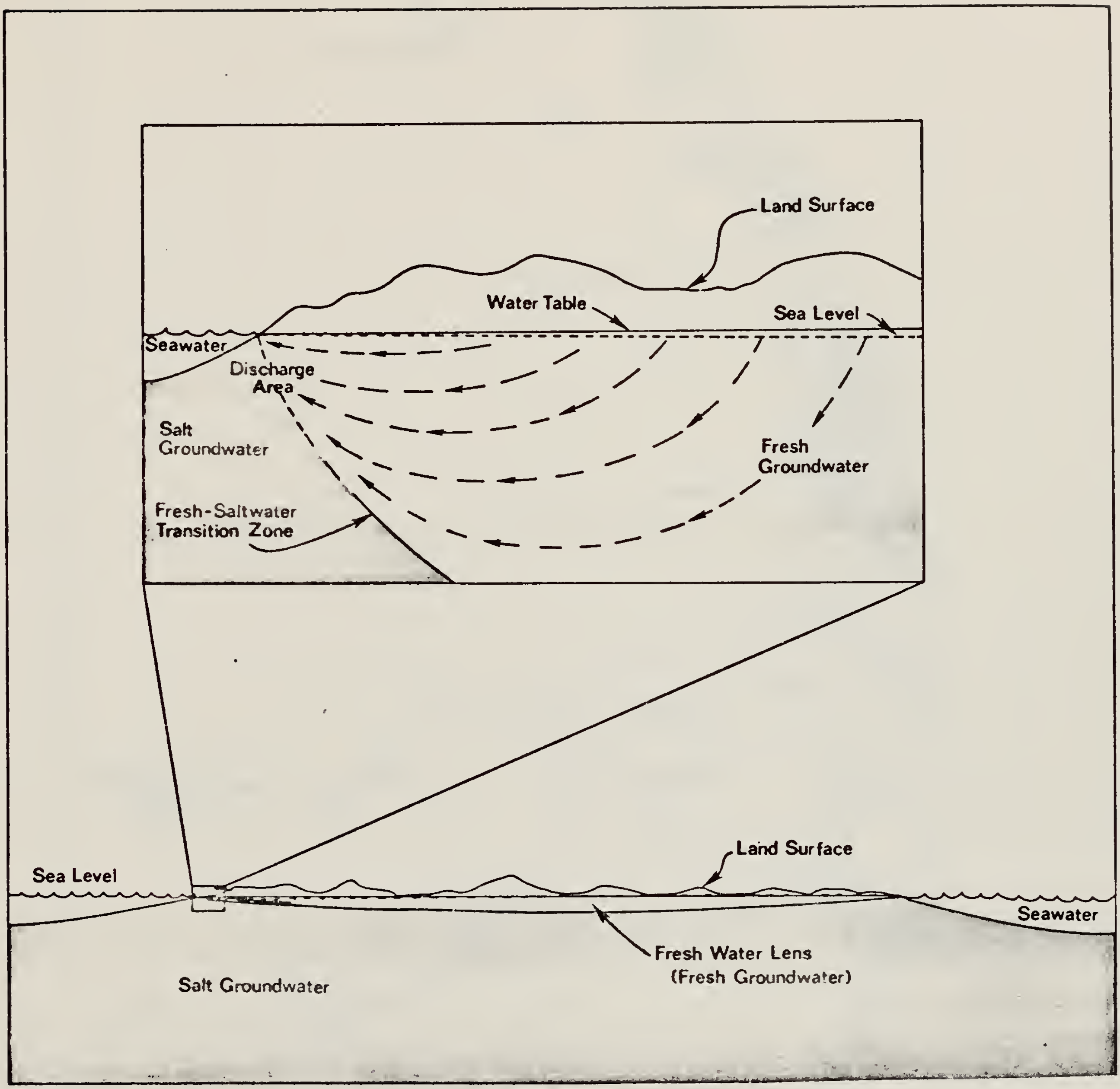

Figure 5 Schematic Cross-sectional Detail of the Outer Cape's Groundwater Aquifer Sub-basin. The diagrams are drawn approximately to scale for a cross-section through the North Truro sub-basin (see Figure 6). The land surface in the lower diagram is approximately 2.5 kilometers (1.5 miles) across from bay to ocean; whereas the upper diagram represents approximately 61 meters (200 feet). The dashed lines indicate areas of uncertainty in the data base.

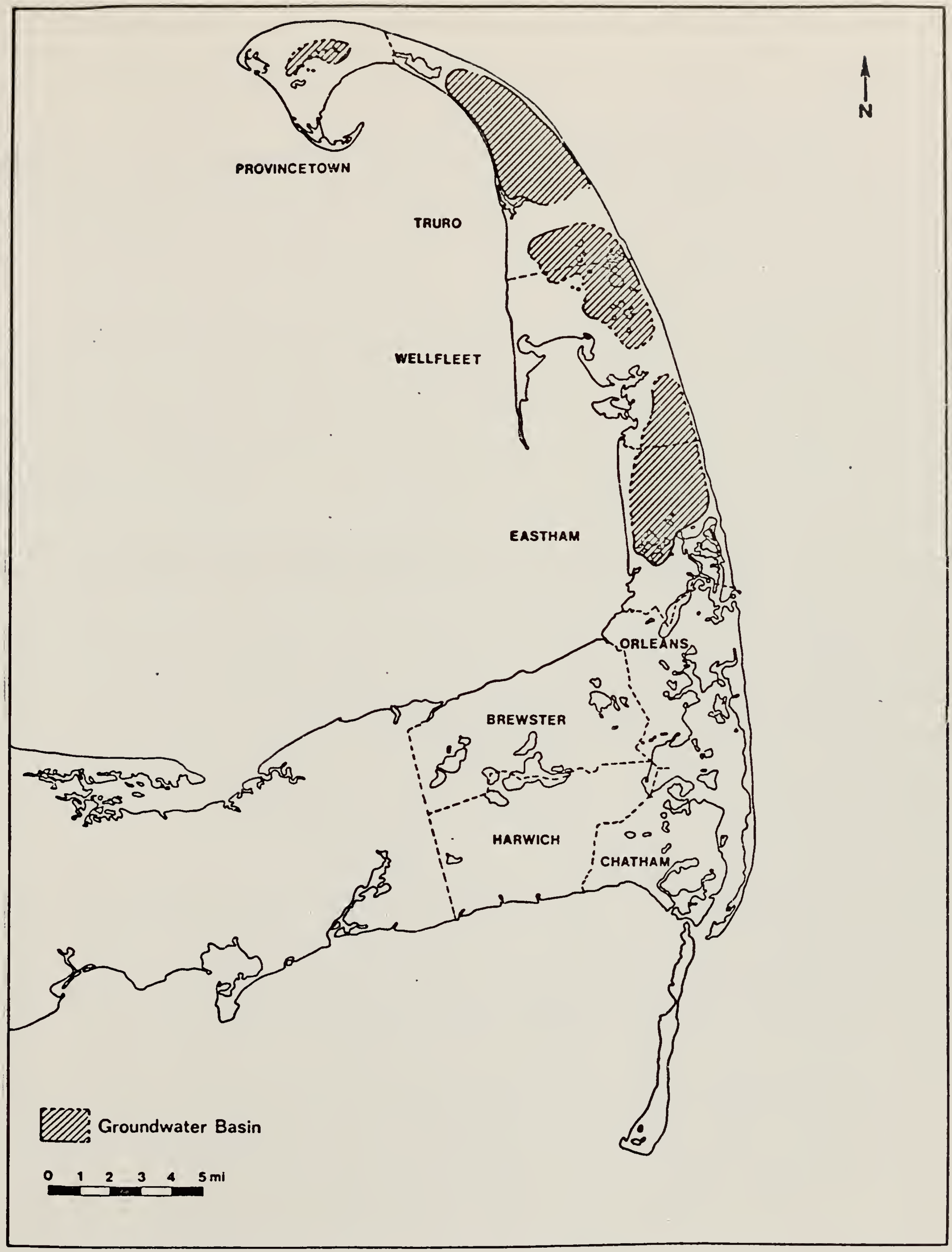

Figure 6 Location of the Groundwater Sub-basins of Outer Cape Cod. The boundaries shown are approximate, for more detail on the water table elevations in each sub-basin, refer to Figures 7-10.

Figure 5

Figure 6-10

2) Ponds and Lakes

The freshwater ponds and lakes of Cape Cod National Seashore can be divided into three types based on the geological history of the pond: (1) dune ponds (2) kettle hole ponds and, (3) coastal ponds. The locations of these and other surface water resources are shown in Figures 11-15.

(a) Dune Ponds

Dune ponds occur in the low interdune areas in the Provincelands. These low areas are created by sand movement, most commonly from wind deflation (producing a "blowout"). Deepening of this low area can occur until the groundwater level is reached and a shallow dune pond is formed. Low interdune areas can also result from the process of dune development. Dunes develop where drift lines were deposited and as the dune ridges grow upward (with the accumulation of windblown sand), the area between the dunes (between the drift lines) remains low. Often this low area between the ridges will persist and become a dune pond (Godfrey *et al.*, 1977; Leatherman, 1979b).

There are over 20 large dune ponds in the Seashore and many more smaller ones, including some that are seasonal. The pond surface levels reflect variations in the elevation of the local water table, since the ponds are surface exposures of groundwater. Most of these ponds are quite shallow and are in the later stages of pond succession with an abundance of plant growth. Drainage from some ponds is limited, causing acidic, low oxygen conditions that favor development of bogs. Clapps and Shank Painter Ponds in Provincetown support prime examples of quaking bogs -- unusual features in a dune area.

(b) Kettle Ponds

Kettle hole ponds, the most common pond type in the non-dune area of the Seashore, were formed during the retreat of the last ice sheet, approximately 12,000 years ago. Blocks of ice left by the glacier were surrounded and covered by sediments carried in the water flowing across the outwash plain from the melting glacier. Eventually these ice blocks melted and deep depressions were formed in the land, resulting in the familiar "knob and kettle" topography that characterizes the Truro-Wellfleet area on the outer Cape (Strahler, 1966).

The kettle hole depressions vary in depth. The deeper ones became filled with fresh groundwater as the sea level rose after glaciation; some ponds are now over 18 meters (approximately 60 feet) deep. These kettle hole ponds are surface exposures of the water table, so they are also called "water-table ponds" or sometimes "open wells". The ecology and limnology of these ponds is described in detail in other publications (MacCoy, 1958; Soukup and Ludlum, 1976; Soukup, 1977; Soukup, 1979). (See also Section IV.B.3).

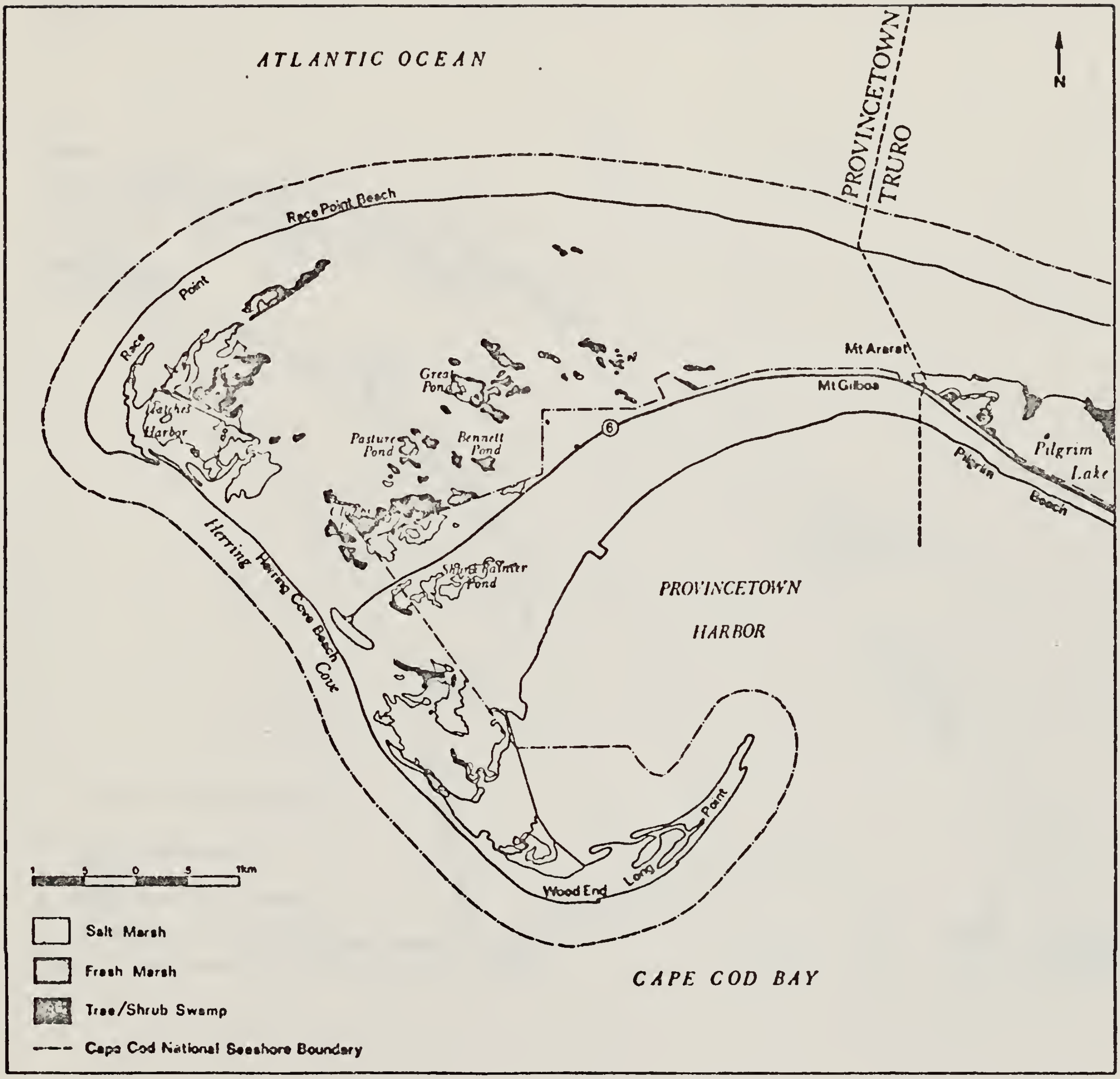

Figure 11 Surface Water Resources of Cape Cod National Seashore: U.S. Geological Survey; Provincetown Quadrangle (Original Scale 1:25,000)

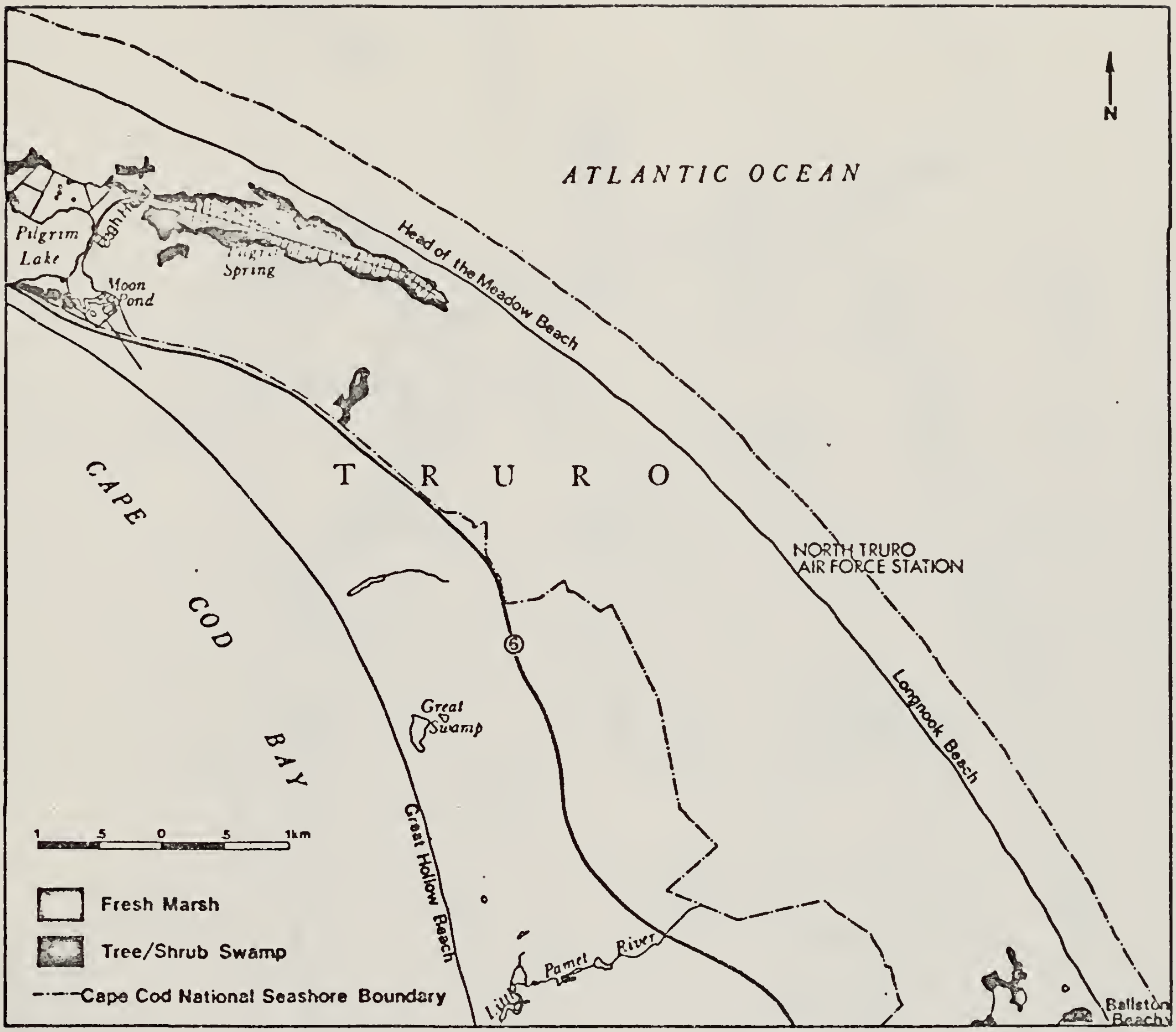

Figure 12 Surface Water Resources of Cape Cod National Seashore: U.S. Geological Survey; North Truro Quadrangle (Original Scale 1:25,000)

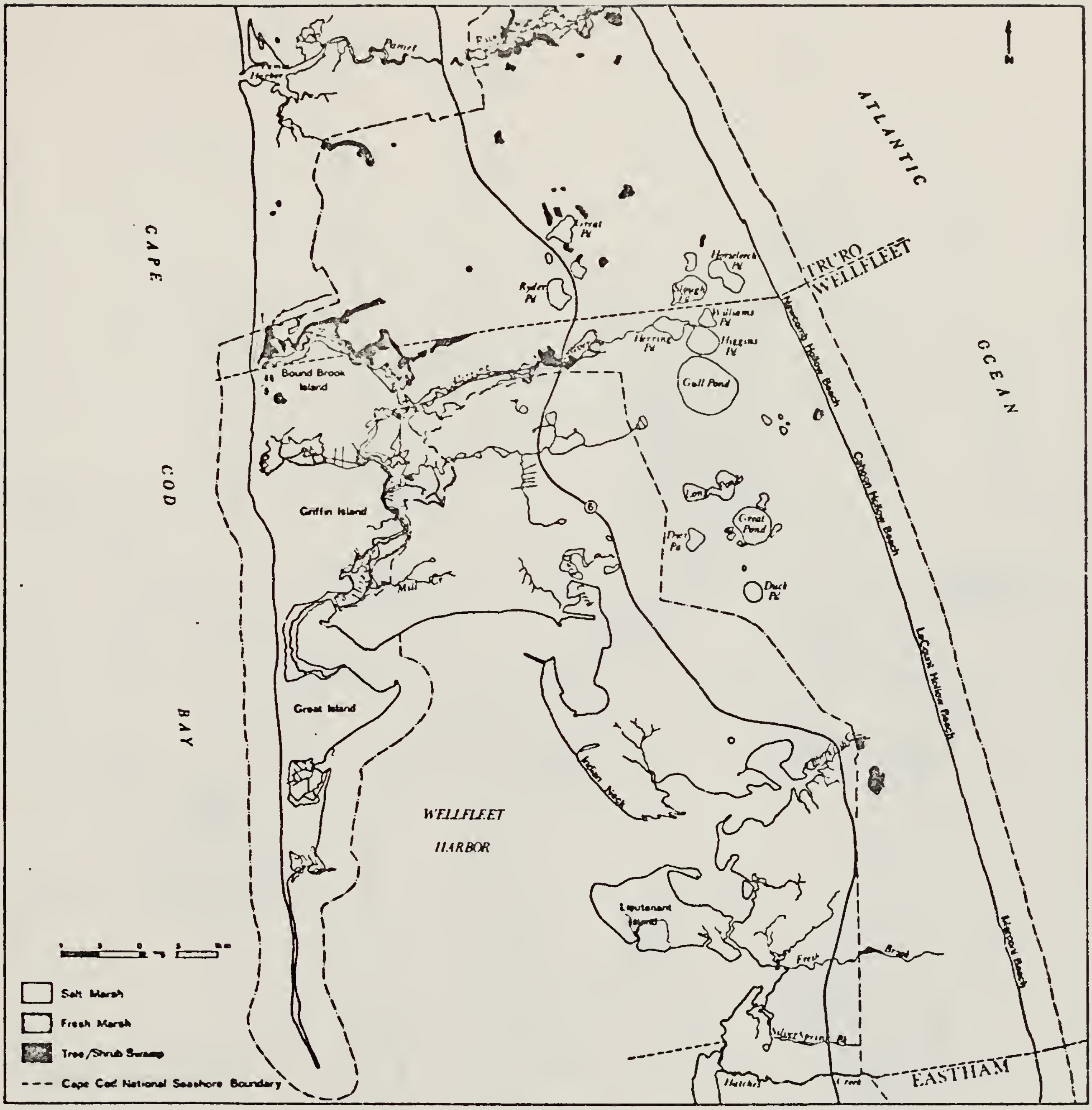

Figure 13 Surface Water Resources of Cape Cod National Seashore: U.S. Geological Survey; Wellfleet Quadrangle (Original Scale 1:25,000)

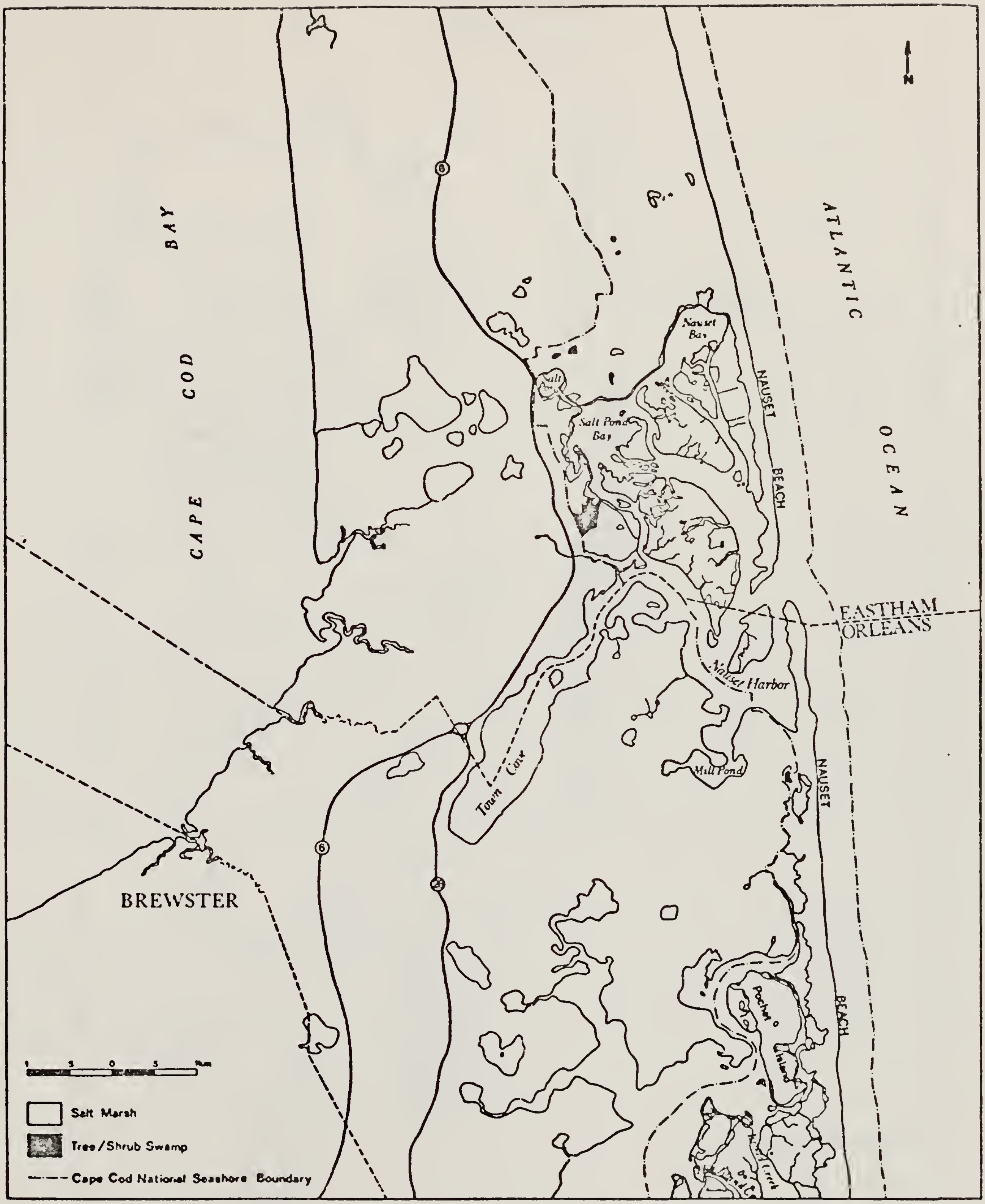

Figure 14 Surface Water Resources of Cape Cod National Seashore: U.S. Geological Survey; Orleans Quadrangle (Original Scale 1:25,000)

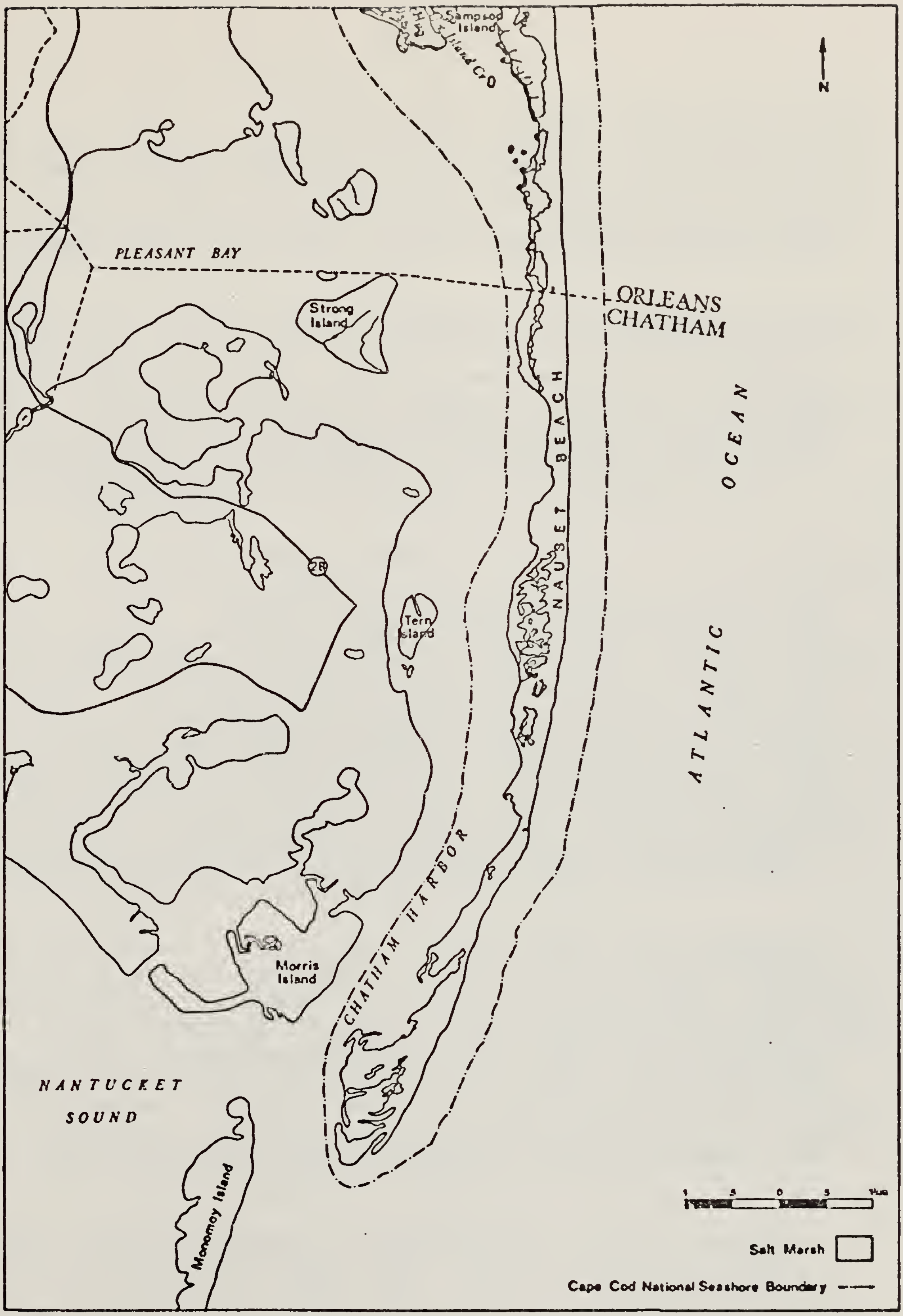

Figure 15 Surface Water Resources of Cape Cod National Seashore: U.S. Geological Survey; Chatham Quadrangle (Original Scale 1:25,000)

(c) Coastal Ponds

Coastal ponds form when ocean bays or lagoons are sealed off by barrier spits created by sediments carried by wind and water currents. If the connection to the sea water is completely severed, the water in the coastal pond is diluted by precipitation and fresh groundwater and becomes brackish or possibly fresh. The only major example of a coastal pond within the Seashore that has been isolated from the ocean is Pilgrim Lake (see Figures 11 and 12).

Historically, the formation of freshening conditions in Pilgrim Lake was accelerated by reinforcement of the natural barrier spit with a road and later railroad. The flow of water is now regulated by tide gates and a weir that normally keep out the seawater. Salinity in the summer of 1979 ranged from 3 to 5 ppt (Portnoy, 1979, unpublished data). Pilgrim Lake is shallow, highly eutrophic and is characterized by large blooms of algae, and periodic midge population explosions (Mozgala, 1974) (also see Section IV.B.5.).

3) Streams and Rivers

Since there is a limited elevation gradient and the glacial sediments are highly porous, there is limited surface runoff and there are few streams and rivers on the outer Cape. The ones that do exist are small and sluggish, often bordered by marshes and swamps (see Figures 11-15). Stream flow originates from precipitation, groundwater seepage or outflow from water table ponds, and the quality of the river water reflects that of the river's source. The two major stream systems within Cape Cod National Seashore are the Herring and Pamet Rivers (see Figures 12 and 13). Both of these rivers follow a channel cut during the glacial outwash period lasting several thousand years. There are also several smaller drainages in the Seashore such as Duck Harbor, Bound Brook, Fresh Brook, and Blackfish Creek (see Figure 13).

The Herring River (in Wellfleet) is approximately five kilometers (3.1 miles) long and has the three features of a river system (headwaters, floodplain and estuary), although on a relatively small scale. The river begins as a small stream about two meters wide, draining Herring Pond which receives water from Williams, Higgins, and Gull Ponds. The floodplain area begins about halfway from Herring Pond to Route 6 where there are extensive bottomlands of marshes and shrub swamps (Godfrey, *et al.*, 1977). Near the mouth, the river widens out into the intertidal estuarine environment. A dike at the mouth of the Herring River partially inhibits the natural tidal flushing of the estuary (see Section IV.B.6.).

There is generally enough flow in the Herring River to prevent freezing in the winter even though there is only a gradual gradient from the source to the mouth (see Appendix P). During the severest winter in recent times (1976-77) the Herring was one of the few aquatic environments

that remained unfrozen, which makes this river an extremely important area for over-wintering wildlife (Godfrey, *et al.*, 1977). The river is also a run for two species of herring. If the fish are successful in passing through the tide gates, they swim upstream and spawn in the streams or the ponds.

The Pamet River flows toward the Bay through a bottomland filled with cattail marshes and shrub swamps. The freshwater portion of the Pamet is 2.5 kilometers (1.6 miles) long, stopping just upstream from the tide gates under Castle Road. East of the dike, the river is under tidal influence and becomes an estuary for the rest of its length to the mouth in the Pamet Harbor.

The portion of the Pamet River within Cape Cod National Seashore is fresh or mildly brackish. No major ponds drain into the Pamet; its water level and flow depend entirely on the groundwater flow under the uplands on either side and on direct precipitation. Headwater uplands once existed but these have been removed by coastal erosion processes. The present headwaters of the Pamet, a freshwater marsh, are slowly being encroached upon as the dune behind Ballston Beach migrates slowly westward with the eroding shoreline (U.S. Army Corps of Engineers, 1979; Godfrey and Godfrey, 1979; Leatherman, 1979a; Godfrey, 1980).

4) Freshwater Marshes

Marshes are wetlands characterized by standing water most of the year. The soil is generally soft muck and is rich with decaying organic matter. During periods when the marshes dry out, usually in late summer, the substrate is exposed, the soil is oxidized and the organic matter can be broken down by bacteria that release nutrients to the entire marsh ecosystem. The drying period and soil exposure are also necessary for the germination of many wetlands plants. When the sediments remain continually underwater, the bottom layers may become low in dissolved oxygen and the decaying process slows down drastically (Smith, 1977).

Freshwater marshes are very productive in terms of plant growth and create a large amount of organic matter. A considerable amount of material can accumulate if it is not broken down or transported away by water flow. Over time, marshes tend to fill up with organic matter and become drier communities.

The dominant freshwater marsh vegetation on the outer Cape is either cattails, reeds, sedges, grasses or forbs (Godfrey, *et al.*, 1977). In certain types of marshes, there is no one dominant species of vegetation (such as streamside and wet meadow communities); rather there is a mixture of wetland plant species. Marsh plants often develop a firm mat of tough fibrous roots that form a solid base in the soft sediments. The maximum water depth tolerated by emergent marsh vegetation is three feet. Reeds can tolerate the deepest water; cattails, sedges, and rushes

generally grow in one foot or less (Smith, 1977). Wet meadow and streamside communities grow primarily in waterlogged areas, although a few occur in areas with standing water.

Most of the marshes of the Seashore are associated with river drainages (the Herring and Pamet Rivers and Bound Brook are good examples); or in formerly intertidal areas (such as Pilgrim Lake and part of Hatches Harbor); or in interdune depressions, associated with dune ponds (see Figures 11-15). The source of water is precipitation and groundwater seepage into the marsh areas. It is possible that some of the wetlands have water tables perched above the groundwater table elevation.

5) Bogs

A Bog is unique ecological community both chemically and biologically. Bogs form in wet areas where drainage is limited and organic matter accumulates (Smith, 1980). The water is usually highly acidic and low in dissolved oxygen, conditions that inhibits decomposition of organic matter. The slow decomposition rate results in an accumula of peat. Nutrients held in the organic peat are not available to the bog community so usually nitrogen, phosphorous and in some cases potassium are in limited supply in a bog. Plant growth is generally slow, thus any disturbance such as foot or vehicular traffic, creates long-term damage to the bog vegetation and the associated bog animals.

a) *Sphagnum* Bogs

Bogs that form in a wet area are sometimes characterized by a mat, often a floating mat, of *Sphagnum* moss and heaths. Over time, the mat may expand and eventually cover the entire pond surface. Standing water may remain under the mat, resulting in a quaking bog, (so-named because the mat shakes when stepped on). Shrubs often invade the mat and a shrub swamp develops that may, over time, become a tree swamp.

Since bogs are characterized by an unusual chemical environment(highly acid and low in nutrients), the species found there are also unusual. Insectivorous plants, such as the sundew and pitcher plant, are present as well as many species of orchids, some of which are rare. The orchid *Arethusa bulbosa* for example, was recently rediscovered near Shank Painter Pond in the summer of 1979 (LeBlond, Outer Cape Environmental Association, pers. comm., 1979).

Bogs are only rarely found in dune ponds yet there are prime examples of quaking bogs in both Clapps and Shank Painter Ponds. Many of the ponds in the kettle hole depressions of Truro and Wellfleet, such as Featherbed Swamp, also support impressive bog communities (see Figures 11-15).

b) Cranberry Bogs

Cranberry bogs deserve special attention because of their relationship to the cultural history of Cape Cod. It was on Cape Cod that the commercial propagation and harvesting of cranberries began, an activity that is still identified with Cape Cod across the nation.

Today Cape Cod has both commercial and wild cranberry bogs. Commercial bogs have been largely developed from red maple swamps, Atlantic white cedar swamps and salt marshes. The water table in these sites is controlled by extensive irrigation and drainage ditches to meet seasonal needs. However, only one cultivated cranberry bog remains within the boundaries of the park, near the Pamet River on the North Pamet Road. This was formerly a commercial bog, of which 1/4 - 1/2 acre has been restored and is maintained as an interpretive demonstration site of 19th Century cranberry production practices.

Wild cranberries *(Vaccinium macrocarpon)* are a minor component of wetlands near Cape ponds, but in the Provincelands there are many areas occupied solely by this species. Some patches cover an acre or more. In some instances pitch pine, inkberry or bayberry are scattered among the cranberry communities (Kaye, NPS, written comm., 1980).

6) Freshwater Swamps

a) Shrub Swamp

A shrub swamp is characterized by a dense, three to four meters high ground cover of shrubs such as swamp azalea, highbush and downy blueberry. The soil is wet, sometimes with standing water, usually less than one foot deep. The soil is usually peaty, and rich with organic matter. Shrub swamps are often found on the edges of marshes and ponds, especially bog ponds.

Many of the interdune hollows in the Provincelands support shrub swamps as well as many of the kettle hole depressions of Truro and Wellfleet (see Figures 11-15). Shrub swamps also occur along streams such as the Herring and Pamet Rivers.

b) Tree Swamp

The soil of tree swamps is usually waterlogged and may be covered with a foot or less of standing water. The trees often become established in a shrub swamp and represent the invasion of the next ecological community in the process of succession.

Within the Seashore there are two types of tree swamps; the Atlantic White Cedar and Red Maple swamp, and the Red Maple and Tupelo community.

The Atlantic White Cedar swamp is restricted to wet areas and the conditions for seed germination (open peat and sunlight) are no longer common on Cape Cod due to ecological succession. Historic logging and cranberry bog development also eliminated many sites. As a result, the Atlantic White Cedar swamp near the Marconi site in South Wellfleet (approximately eight acres), a young stand in the Provincelands, and two stands in Eastham are the only four areas of this community within the Seashore (see Figures 11-15).

The Red Maple-Tupelo swamp is more common. Red maple survives well in both wet and dry areas, so some Red Maple stands are found in terrestrial habitats. There are Red Maple-Tupelo stands near the Fort Hill Nature Trail, in Paradise Hollow, along portions of the Pamet River, and in low-lying areas of the Province Lands.

b. Saltwater Environments

The boundary of Cape Cod National Seashore extends seaward from park land for 1/4 mile (see Figure 2). The saltwater resources of the Seashore therefore include open shallow marine and estuarine waters, and the adjacent intertidal areas. These saltwater resources are all influenced by the tidal cycle, by ocean currents and by the influx of fresh river and groundwater into the coastal waters. Intertidal communities are some of the most biologically productive ecosystems. Much of the productivity of these inshore waters is exported offshore to deeper waters; the influence of shallow water productivity may extend as far as the edge of the continental shelf.

1) Open Marine

a) Coastal Waters

These shallow coastal waters have fairly constant salinity averaging 33-35 parts per thousancd (ppt) (Largely sodium chloride), are weakly alkaline (pH 8.0 to 8.3), and are strongly buffered. Shallow marine waters are influenced by the offshore ocean environment as well as "outwelling" from nutrient-rich estuarine waters (Odum, 1971). There are also terrestrial influences such as groundwater seepage and surface runoff; that is most notable in estuaries.

There is appreciable sediment transport in the shallow coastal waters along the Cape. Longshore currents created by waves striking the shoreline at an angle. Along the eastern shore of the Cape, this longshore drift is a significant factor in reshaping the coastline (U.S. Army Corps of Engineers, 1979). Wave action is a significant factor, especially during the winter. In addition to longshore currents, water and sediment can be transported offshore by rip currents.

In general, the marine floor within the Seashore boundaries, is relatively flat, and slopes gently out to deeper waters. The substrate of the shallow marine areas is predominantly bare sand with some silt and

clay plus organic remains such as shell deposits. Submerged eelgrass beds occur in sheltered coastal areas and are productive communities that supply nutrients to support numerous marine organisms (Phillips, 1974). The occurrence of eelgrass beds is not well documented but some beds have been located in Cape Cod Bay off Great Island and Jeremy Point, and in Pleasant Bay, Town Cove, Nauset Bay, Salt Pond Bay, Wellfleet Harbor and Provincetown Harbor (Godfrey, *et al.*, 1977). This shallow coastal environment plays an important role in the life cycle of many species of shellfish and fin fish, providing a habitat for both young and adult forms and spawning areas (Odum, 1971).

b) Estuarine

Historically, an estuary has been defined as the coastal waters at the mouth of a river where fresh and saltwater mix. However, there are certain characteristics of an estuary that are found in areas other than the mouth of a river, so the definition was broadened to include semi-closed coastal bodies of water which have a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage (Pritchard, 1967).

Estuaries are influenced by the marine waters brought into the estuary by the tides, as well as the freshwater entering the system from the land. The circulation patterns of the water in an estuary can serve to hold nutrients and oxygen in the area which may partially explain the high productivity observed (Correll, 1978). In fact, salt marshes and estuaries together form one of the most productive of all ecosystems (Smith, 1980). The role of coastal salt marshes and barrier spits in flood protection is discussed elsewhere (O'Connor and Terry, 1972; Commonwealth of Massachusetts, CZM Program, 1978).

Most estuaries are bounded by intertidal salt marshes near the mouth. Further up the estuary, as the water becomes more fresh, the marsh vegetation changes to a freshwater community. It is the marsh bordering an estuary that contributes a large portion of the organic production. Many estuaries also support underwater vegetation such as eelgrass beds and various types of algae.

There are no unaltered estuaries at the mouth of rivers within Cape Cod National Seashore. The Herring River, the only major stream draining into the sea within the boundaries of the park, is partially blocked by a dike with tide gates that prevent the normal mixing of sea- and freshwater (see Section IV.B.6). There is, however, a limited estuarine environment at the mouth of the Herring River above and below the dike. There are also enclosed, large lagoonal estuaries in Hatches Harbor, the Salt Pond-Nauset Marsh area, Pleasant Bay, and Chatham Harbor (Godfrey, *et al.*, 1977; Commonwealth of Massachusetts, CZM Program, Volume I and II, 1978).

2) Intertidal

a) Tidal Mud and Sand Flats

Tidal flats are intertidal areas protected from heavy wave turbulence, and include both sand flats and mud flats. Sand flats, often associated with barrier spits, are generally less protected from wave action than mud flats and are subject to constant sand movement. In the more protected areas of a sand flat, algal mats develop. Benthic fauna colonize the area and stabilize the bottom sediments. As organic matter accumulates and mixes with the sand, mud flats are formed. Eventually salt marsh plants become established and the area that was once bare sand can become covered with salt marsh vegetation.

In Cape Cod National Seashore, major sand flats occur on the northwest side of Hatches Harbor, on Nauset Spit, at Coast Guard Beach, and Wood End. Mud flats are found at Great Island, Nauset Harbor, and Wellfleet Harbor (Godfrey, *et al.*, 1977). Mudflats are generally found on the periphery and at the expanding edges of salt marshes.

b) Salt Marsh

Salt marshes have their origin in sheltered coastal areas on mud and sand flats where organic matter accumulates (Redfield, 1965 and 1972). Salt marsh sediments are characterized by dark, very fine particles, rich in organic matter called peat. The peat underlying most salt marshes on Cape Cod varies in thickness between one and three meters. The peat layer under the Nauset Marsh system is approximately two meters thick (Niedoroda and April, 1975).

Tidal range, composition of the substrate, slope of the shoreline and freshwater seepage are factors that influence salt marsh vegetation and create zones of plant species in the marsh (Smith, 1980). Tidal range is probably the most significant factor in zonation, since many species are limited by their tolerances to submersion in saltwater. Salt water cordgrass *(Spartina alterniflora)*, the first plant species to colonize a flat, grows at the edge of the tidal range (usually from mean low to mean high tide) but cannot tolerate continued submersion. The area covered by cordgrass is often referred to as the low marsh. Growing between the tall cordgrass is a dwarf form of *Spartina alterniflora.* Above, in the high marsh (about two inches above mean high water), marsh hay cordgrass *(Spartina patens)* and spike grass grows. Two characteristic features of a salt marsh are meandering creeks, pond holes, pannes that often remain flooded at low tide.

Salt marshes are highly productive ecosystems and produce a great deal of organic matter, most of which is flushed out by the tides into other coastal systems, such as estuaries and shallow marine waters (Nixon and Oviatt, 1973). There is evidence the exported products may even supply energy and materials to communities in the waters above the continental shelf (Odum, 1971). Marshes, like estuaries, provide habitats for

many marine organisms during all or part of their life cycles, including many commercially valuable species of fin and shellfish.

In Cape Cod National Seashore salt marsh systems occur at Long Point/Wood End, Hatches Harbor, Great Island (just south of the area known as the Gut), and the lower reaches of the Herring-River (see Figure 11-15). A prime example occurs at Nauset Marsh (see Figure 17).

c) Rockweed-Barnacle Communities

This intertidal community is characteristic of rocky shores and so is relatively uncommon on Cape Cod and restricted to large glacial boulders, dikes and jetties within the range of the tides. The tidal range creates a zonation of organisms. Other influences on the pattern of zonation include wave action, light intensity and slope of the surface. There are basically three major zones named for the predominant organisms: periwinkle zone with black (blue-green) algae and lichens, barnacle zone and seaweed or rockweed zone (Gifford and Odum, 1961; Smith, 1980).

The productivity of this community is probably quite high but difficult to measure. The water is continually flushed seaward by tides and wave action, so the energy and nutrients from this rocky intertidal community enter other coastal marine systems.

Large rocks like the ones west of Great Island and at the north end of Nauset Beach support rocky intertidal communities. The dikes from Provincetown to Wood End, at Hatches Harbor and at the Herring River also support similar communities (see Figures 11-14).

c. Floodplain

Floodplains are areas of land that are susceptible to being periodically inundated by either river or coastal waters, but are normally not submerged. The 100-year floodplain (also called the bare flood) is an area with a 1% (or greater) chance of flooding in any given year; a 500-year floodplain has only a 0.2% chance of flooding. The 100-year floodplain of outer Cape Cod has been identified and mapped (see Figures 16-20) (see Section III.B.6.).

Floods are often discussed only in terms of the damage they cause. Actually, periodic coastal or inland flooding is a normal, natural process and may in some cases be beneficial to the flooded area (by adding nutrients and moisture to the soil).

Riverine floodplains are an integral part of a river system that transports the excess water during times of heavy waterflow. On Cape Cod increased river flows are generally shown by a delayed response to rainfall. The maximum rise in stream levels during flood periods (for all

Figure 16-20

of Cape Cod) was found to be one to two meters (New England River Basins Commission (NERBC), 1975). Even so, there has been no significant riverine flooding problems on the Cape (NERBC, 1975). The explanation for minimal riverine flooding observed is related to the pervious nature of the Cape's soils.

Coastal flooding is more extensive than riverine flooding on Cape Cod. Coastal flooding is caused by above-normal tides, storm surge and high waves associated with storms, usually northeasters or hurricanes. The low lying coastal areas subject to flooding represent a diversity of coastal landforms (beaches, dunes and wetlands) each of which may buffer the wave energies and tidal surges and provide valuable flood protection for adjacent areas (NERBC, 1975; Commonwealth of Massachusetts CZM Program, 1978) The coastal and riverine floodplains within Cape Cod National Seashore overlap many of the other types of water resources (rivers, ponds, inland and coastal wetlands).

6. Animals and Plants Associated With the Water Resources of Cape Cod National Seashore

Phase I of the Seashore's Natural Resource Management Plan lists many of the common plant and animal species associated with the various types of water resources. However, since there are major gaps in the data base on the biota within these communities on the outer Cape, this resource inventory is seriously incomplete.

There is a similar paucity of data on the rare, threatened and endangered species. However, several agencies are currently gathering information. The Massachusetts Natural Heritage Program (within the Department of Environmental Management) is compiling all known information on rare, threatened and endangered plant and animal species*, as well as the geographic location of ecosystems and landscape features in Massachusetts. The U.S. Fish and Wildlife Service is also conducting field investigations on the nationally significant species. The staff of Cape Cod National Seashore is compiling information on rare species within the park. In addition, many local people are providing information to these agencies from their first-hand knowledge of the area.

*
The term endangered indicates that a species' continued existence over its entire range is in serious question. A threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. A rare species, although not threatened or endangered over its entire range, is either declining in Massachusetts, restricted to very limited geographic areas, or widespread but infrequent (Mass. Natural Heritage Program, written comm., 1980).

Table III lists the plant and animal species known to be endangered, threatened or rare on outer Cape Cod. As of March 1980, there were 17 endangered species or threatened species known to occur in Massachusetts, nine of these species are known to occur on outer Cape Cod or in the surrounding waters. All of these species are associated with water resources. There are 21 rare species known to exist currently or historically on the outer Cape; 12 of these species are associated with water resources.

B. Present Status of the Water Resources of Cape Cod National Seashore

1. History of Land Use and Population Growth on the Outer Cape

The geology and climate of the area determine the natural background quantity and quality of water and also determine the dynamic environment in which natural systems evolve. Superimposed on the natural background conditions is the impact of human activities on water resources. Humans are in a unique position in relation to natural ecosystems because we are able to influence and alter entire ecosystems. Consequently, to assess the current status of water resources, it is important to understand the past, current and projected human activity on the outer Cape.

a) Brief History of Population Growth

Since the mid-1900s, both the Cape's population and the number of tourists have grown rapidly. Cape Cod had an annual population increase of 4% in the 1950s and 3% in the 1960s; during these same decades the Commonwealth of Massachusetts had an annual increase of only 1% (CCPEDC, 1978a). Between 1950 and 1975, the year round population on the outer Cape increased 95%, almost 4% per year (see Table IV). The outer Cape experienced even more rapid growth in the early 70s. Between 1970 and 1975, the population on the outer Cape increased 34%, almost 7% per year.

The population projections for the outer Cape estimate the annual rate of growth will decline to around 2%, the pre-1970 average level (Herr and Associates, 1976). Recent comparisons between the current and projected populations indicate the year-round population growth is following the projected pattern (Herr, pers. comm., 1980).

Tourism and the seasonal population have also increased during the last few decades. In 1950, the summer population on Cape Cod was approximately 155,000; 110,000 of which were seasonal residents. By 1976, the seasonal population had more than doubled (CCPEDC, 1978a). The pattern on the outer Cape is similar. By 1995, increasing at a 2% annual rate, the seasonal population on outer Cape Cod is projected to be 123,000, or an average density of 1061 people per square mile (see Table V). The seasonal population is generally three times year-round population.

Table III. Rare, Threatened, and Endangered Species on Outer Cape Cod and Surrounding Waters.

Common Name	Scientific Name	Rare, Threatened or Endangered Status*	Associated with Water Resources	Extant Status	Comments	Reference
1. Animals:						
Four-toed Salamander	*Hemidactylium scutatum*	Rare	Yes	?	Historically present	Mass.Natural Heritage Program, 1980
Spade-foot Toad	*Scaphiopus holbrooki holbrooki*	Rare	Yes	?	" "	
Box Turtle	*Terrapene carolina carolina*	Rare	Yes	Extant	Population on Cape Cod may be important since populations are declining in other parts of Massachusetts	Portnoy,pers.comm. 1980
Diamond- backed terrapin	*Malaclemys terrapin*	Rare	Yes	Extant	Northern Limit of breeding range. Small number nests near Great Island and possibly elsewhere Historically abundant in Pleasant Bay	Portnoy,pers.comm. 1980
Green Turtle	*Chelonia mydas*	Endangered	Yes	Extant	Sub-adults feed in Cape Cod Bay.	Prescott,written comm. 1980
Leatherback Turtle	*Dermochelys coriacea*	Endangered	Yes	Extant	Migrate by Cape Cod and feed in Cape Cod Bay	" " "
Loggerhead Turtle	*Caretta caretta*	Threatened	Yes	Extant	Sub-adults feed in Cape Cod Bay	" " "
Kemp's (or Atlantic) Ridley Turtle	*Lepidochelys kempii*	Endangered	Yes	Extant	Sub-adults feed in Cape Cod Bay	" " "
Bald Eagle	*Haliaeetus leucocephalus*	Endangered	Yes	Extant	Occasionally young eagles fish the ponds on the Cape	Portnoy,written comm. 1980
Peregrine Falcon	*Falco peregrinus*	Endangered	Yes	Extant		
Roseate Tern	*Sterna dougallii*	Under consideration for Federal endangered species status	Yes	Extant	Small numbers nest at Nauset Marsh. Many feed and rest in estuaries and along barrier beaches on the Cape.	" " "
Finback Whale	*Balaenoptera physalus*	Endangered	Yes	Extant	Migrants and Summer residents. Cape Cod Bay and, in particular waters off Race Point (Provincetown) and Pollack Rip (Chatham) are important feeding areas Right Whales may go through courtship behavior in Cape Cod Bay.	Prescott, written comm. 1980
Humpback Whale	*Megaptera novaeangliae*	Endangered	Yes			
Right Whale	*Eubalaena glacialis*	Endangered	Yes			

*Threatened and endangered status is federally determined in reference to the entire range of a species, according to the Federal Endangered Species Act of 1973. Rare status indicates species that could under certain circumstances, be adversely affected or extirpated from Massachusetts, although not necessarily from their entire range.

Table III. (continued) Rare, Threatened and Endangered Species on Outer Cape Cod and Surrounding Waters.

Common Name	Scientific Name	Rare, Threatened or Endangered Status*	Associated with Water Resources	Extant Status	Reference
2. Plants:					
Slender Arrowhead	*Sagittaria teres*	Rare	Yes	Extant	Glen Kaye, Cape Cod National Seashore written comments, 1980
Sea Lime Grass	*Elymus arenarius*	Rare	No	Extant	
Panic Grass	*Panicum commonsianum* var. *commonsianum* and var. *addisonii*	Rare	No	Extant	" " " "
Spike Rush	*Eleocharia melanocarpa*	Rare	Yes	Extant	" " " "
Dwarf Umbrella Grass	*Fuirena pumila*	Rare	Yes	Extant	" " " "
Golden Club	*Orontium aquiticum*	Rare	Yes	Extant	" " " "
Blue-eyed Grass	*Sisyrinchium arenicola*	Rare	No	Extant	" " " "
Swamp Pink	*Arethusa bulbosa*	Rare	Yes	Extant	" " " "
Post Oak	*Quercus stellata*	Rare	No	Extant	" " " "
Seabeach Knotweed	*Polygonum glaucum*	Rare	No	Extant	" " " "
Rich's Sea Blight	*Sueda richii*	Rare	Yes	Extant	" " " "
Thread-leaved Sundew	*Drosera filiformis*	Rare	Yes	Extant	" " " "
Broom Crowberry	*Corema conradii*	Rare	No	Extant	" " " "
Common Persimmon	*Diospyros virginiana*	Rare	No	Extant	" " " "
Plymouth Gentian	*Sabatia kennedyana*	Rare	Yes	Extant	" " " "
Butterfly-weed	*Asclepias tuberosa*	Rare	No	Extant	" " " "
Two-flowered Bladder-wort	*Utricularia biflora*	Rare	No	?	" " " "

*Threatened and endangered status is federally determined in reference to the entire range of a species, according to the Federal Endangered Species Act of 1973. Rare status indicates species that could under certain circumstances, be adversely affected or extirpated from Massachusetts, although not necessarily from their entire range.

Table IV. Past and Projected Year-Round Population on Outer Cape Cod

Year	Population	%Increase	% Annual Increase	Density People/Sq. Mile*
1950	10,655**			92
		47% (20 yrs)	2%	
1970	15,400**			134
		34% (5 yrs)	7%	
1975	20,800†			179
		47% (20 yrs	2%	
1995	30,600††			264
		62% (32 yrs	2%	
2027	49,700††			429

* Land area of the Outer Cape = 115.92 square miles (U S ACE, 1979)

** From Census Data

† Current Estimate (U S ACE, 1979)

†† Population projections by Herr and Associates (1976), modified in U.S. ACE (1979).

Table V. Past and Projected Seasonal (Summer Resident) Population on Outer Cape Cod*

Year	Seasonal Population	% Increase	% Annual Increase	Density People/Sq. Mile**
1975	89,600			773
		37%	2%	
1995	123,000			1061
		17%	1%	
2027	143,300			1236

* Adapted from U S ACE, 1979. Projections are based on Herr and Associates, 1976.

** Land area of outer Cape = 115.92 square miles (U S ACE, 1979)

Table VI. Total visits to Cape Cod National Seashore*

YEAR	TOTAL VISITS
1964	1,849,875
1965	2,306,133
1966	2,830,288
1967	3,040,509
1968	3,475,842
1969	4,031,258
1970	3,987,001
1971	4,188,300
1972	4,972,281
1973	4,741,975
1974	4,359,393
1975	5,222,895
1976	5,018,707
1977	5,348,852
1978	5,025,902
1979	3,947,353

* From Cape Cod National Seashore Data

Table VII Land Use Changes on Outer Cape Cod*

Land Use	1951	1971	Acreage Change	Direction of Change	% Change	% Annual Change
Total Urban	3,672	12,074	8,402	Increased	+229	+11
Forest	33,646	33,303	343	Decreased Slightly	-1	-.05
Agriculture	17,172	8,879	8,293	Decreased	-48	-2
Wetlands	19,066	19,300	234	Increased Slightly	+1	+.06
TOTAL	73,556					

* Data from MacConnell, 1973.

Many people also visit the Cape for a day or a few days. Since the 1960s, according to National Park Service Records, millions of people each year have visited Cape Cod National Seashore and the surrounding communities (see Table VI).

b) Resource and Land Use Changes

The rapid population growth and the increase in tourism have created changes in land and resource use on the outer Cape that can impact water resources. More people in an area increases the amount of resources used and can also affect resource quality. In terms of water resources, demand for water increases. On the outer Cape the amount of groundwater pumped increases, since groundwater is the only source of drinking water. The amount of sewage and solid waste disposed in landfills increases and can contribute to eutrophication and chemical contamination of water resources. Leakage of stored chemicals, road salting programs, and use of fertilizers, pesticides and herbicides may all result in degradation of water quality. In addition, due to the increased demand for land, there is pressure to drain and fill wetlands, to build in the floodplain, and to control coastal erosion and flooding (with seawalls, groins, dikes, jetties, etc.) Increased harbor use for commercial and recreational boats can create water quality problems from addition of sanitary wastes and chemicals (such as hydrocarbons and toxic metals). Certain types of boating also requires dredging to keep navigation channels open. Silt from dredging and construction may accumulate in coastal waters and disrupt the native plant and animal communities. Disposal of the dredge spoil is another possible source of water contamination.

Although the land within Cape Cod National Seashore is protected from development and many other activities with potential impact on water resources, the land uses on areas adjacent to the park or on non-federal land within the park boundaries can impact the parks resources. In addition, park-related activities, such as recreational use, can also impact water resources. The park does, under certain circumstances, issue special permits for non-park use of park land.

The changes in land use on the outer Cape over a 20-year period are summarized in Table VII. The increase in amount of developed land and the decrease in agricultural land are the most dramatic changes.

The projected land use indicates the outer Cape will reach saturation levels in terms of land available for development by 2047 (U.S. Army Corps of Engineers (USACE), 1979). Provincetown is currently very near saturation since there are less than 100 acres of developable land remaining. The impacts from the increase in population and urban land use of the outer Cape may result in problems concerning both the quality and supply of the water resources.

2. Vulnerabilities of Water Resources to Impacts from Human Activities

The nature of each water resource, the source of water and the relationship to other water resources, render certain water resources vulnerable to alteration and degradation from adjacent land use and human activities. Table VIII lists some activities with possible adverse impacts on the water resources of the outer Cape and indicates the water resources vulnerable to each type of impact.

3. Human Uses of the Water Resources of Cape Cod National Seashore

One of the purposes of the Water Resources Management Plan is to identify and inventory the present human uses and benefits derived from the water resources of Cape Cod National Seashore. This purpose is derived partially from the tradition of establishing water quality standards for the requirements of human use. However, in a national park, it is important to emphasize the inherent biological needs of the ecosystems as well as the human needs. National Park Service policies emphasize ecosystem peresrvation. Human use of resources such as water in general, depend on ecosystem preservation for continued resource availability. Whenever possible, the National Park Service tries to insure the continuation of human uses of water resources that are compatible with long-term preservation of those resources.

The following human uses and benefits have been identified for certain water resources of Cape Cod National Seashore.

- Recreation, non-contact (nature study, National Park Service interpretive programs, birding, fishing, boating, berry picking, shellfishing, beachcombing, hunting)
- Recreation, contact (swimming)
- Maintenance of historic setting
- Aesthetic (contemplative enjoyment, artistic inspiration)
- Water, drinking water supply (non-public, public, municipal)
- Non-drinking water supply
- Flood protection

Table IX indicates the types of water resources which provide these uses and benefits.

4. Water Quality

Federal and State water quality standards are based on present conditions as well as intended water uses. There are federal drinking water standards established under Safe Drinking Water Act of 1974 and Massachusetts Drinking Water Regulations (under authority of Department of Environmental Quality Engineering) (see Appendix F).

Table VIII Vulnerabilities of Water Resources to Impacts from Human Activities

Human Activities with Potential Impacts on the Water Resources / Water Resources Impacted	GROUNDWATER	PONDS AND LAKES	STREAMS AND RIVERS	FRESHWATER MARSHES	BOGS	FRESHWATER SWAMPS	OPEN MARINE	INTERTIDAL	FLOODPLAIN
. groundwater withdrawal	X	X	X	X	X	X	X	X	
. surface and subsurface land uses that contaminate groundwater and surface water resources									
landfills	X	X	X	X	X	X	X	X	X
wastewater disposal	X	X	X	X	X	X			
storage and use of chemicals (road salt, gasoline, herbicides, pesticides, fertilizer, etc.)	X	X	X	X	X	X			
. combustion of fossil fuels	X	X	X	X	X	X			
. pest control									
ditching marshes	X		X	X			X		
pesticide and herbicide application	X	X	X	X	X	X	X	X	X
dikes		X	X	X				X	
. flood control									
dikes		X	X	X				X	
. heavy recreational use (including foot or		X		X	X	X		X	X
vehicular traffic)		X		X	X	X		X	
. dredging for navigation							X	X	
. tanker or pipeline oil transport							X	X	

Table IX Human Uses of Water Resources of Cape Cod National Seashore including National Park Service Interpretive Activities Existing National Park Service Interpretive Foot Trails are indicated with an asterisk, "*".

USE / WATER RESOURCE**	RECREATION, NON-CONTACT	CONTACT	MAINTENANCE OF HISTORIC SETTING	AESTHETICS	DRINKING WATER	NONDRINKING WATER SUPPLY	FLOOD PROTECTION
Freshwater							
Groundwater					X	X	
Ponds:							
Dune	X			X			
Kettle	X	X	X	X			
Coastal	X			X			
Streams and Rivers	X			X			
Freshwater Marshes	X*			X			
Bogs	X*		X	X			
Freshwater Swamps	X*			X			
Salt Water							
Open Marine	X*	X		X			
Intertidal	X*			X			X
Floodplain	X			X			X

*indicates National Park Service Interpretive foot trails.

**For description of Water Resources see Section III.A.5.

There are also water quality standards for surface water established under Federal Water Pollution Control Act of 1972 (as ammended in 1977) and the Massachusetts Clean Waters Act (Massachusetts G.L. Chapter 21, sections 26-53, inclusive). There are currently no water quality standards for groundwater.

The quality of the surface water on Cape Cod is generally above the minimum standards, however, in the 1978 Massachusetts Water Quality Standards, there is an "antidegradation" clause that protects the existing high water quality from deterioration. In addition, all surface waters in and adjacent to Cape Cod National Seashore have been designated National Resource Waters (Regulation 4.4), the highest protection category. All coastal waters off Cape Cod are also designated as an ocean sanctuary (Massachusetts G.L. Chapter 132a. Sections 13, 14, 15).

The natural water quality for fresh surface freshwater, groundwater, and coastal water differ, so the existing data and present conditions will be reviewed separately in the following sections.

a) Freshwater Quality

The natural freshwater quality is primarily a result of soils and geology in an area. The outer Cape is predominantly glacial outwash plain deposits that have a high content of quartz stones with some clay and marsh deposits. The glacial till is resistant to erosion and, so, in general, the freshwater is low in nutrients (phosphate and nitrogen), low in minerals (especially calcium, magnesium, and silica), low in total dissolved solids, soft, acidic and poorly buffered (Soukup, 1977; U.S. Geological Survey, 1979). The quality of freshwater is also influenced by the chemistry of rain water, interactions with the soil and micro-organisms, ocean spray, and most importantly in terms of management, by human activities in the watershed.

Fresh Surface Water Quality

The data for the fresh surface waters, although somewhat limited indicate these resources generally remain in good condition. All fresh surface water is classified as "B" by the Massachusetts Water Quality Standards. "B" waters are suitable for "protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation" (Commonwealth of Massachusetts, Water Resources Commission, 1978). There are no known violations of these standards within Cape Cod National Seashore; however, there are data that suggest some water quality problems exist within the park (CCPEDC, 1978a; Soukup, 1977; Ortiz, Levine and Ward, 1978).

Studies on the kettle ponds in Truro and Wellfleet show certain ponds have increased algal productivity, low dissolved oxygen in the pond bottom layers, and elevated levels of total phosphate phosphorous that are signs of eutrophication (see Appendix G) (Soukup and Ludlum, 1976;

Soukup, 1977; CCPEDCa, 1978). Since these are glacial ponds with naturally low nutrient levels and slow rates of succession, it appears that human activities are accelerating the natural succession rate, a phenomenon called cultural eutrophication. Pilgrim Lake also shows signs of cultural eutrophication (Mozgala, 1974). The 208 Plan for Cape Cod, after a survey of pond water quality, identified artificially accelerated eutrophication as the most significant long term water quality threat to the Cape's surface waters and coastal embayments (CCPEDC, 1978a). (For more detailed information on Kettle Pond Management see section IV. B.3 and 5.) The Massachusetts Division of Water Pollution Controls (DWPC) conducted a pond water quality study in the summer of 1980 under the 314 Lake Classification Program.

Bacterial contamination of ponds is another water quality concern. Bacteriological surveys on many of the kettle ponds in Truro and Wellfleet were conducted for the National Park Service in 1975 and 1976 (Ortiz, 1976a and 1976b; Sousa, 1976; Ortiz, Levine and Ward, 1978). Comparison of the observed bacterial concentrations with the standards for recreational waters (see Appendix F) showed that the ponds were generally well below the standards and free of any serious helath problems. (see Appendix G.4.). However, this research did occasionally detect the presence of certain human pathogens at levels above standards in certain ponds for short term periods (usually not on consecutive days). A study done for the Cape Cod 208 plan showed that coliform levels in several ponds were lower in the winter months than in the summer. These data suggest that the intense recreational use of the ponds in summer increases the bacterial levels (CCPEDC, 1978a).

The surface water assessment for the 208 Plan also revealed high ammonia-nitrogen (greater than .02 ppm) in Pilgrim Lake and high lead levels (greater than .01 ppm) in Great Pond in Wellfleet (CCPEDC, 1978a; Environmental Management Institute, 1976). Elevated ammonia-nitrogen levels usually indicate the presence of large amounts of nitrogenous organic matter either naturally occurring or introduced by human activities such as septic systems. (For more information on Pilgrim Lake water quality, see Section IV.B.5.) The extent and source of lead contamination in Great Pond are presently unknown.

In 1976, the Massachusetts Division of Water Pollution Control (DWPC) surveyed surface water quality of Cape Cod including samples from the Herring and Pamet Rivers and Fresh Brook (see Appendix H) (DWPC, 1976 and 1977). Five freshwater or brackish stations sampled in this study are within or adjacent to the Seashore boundaries. These data indicate the general high quality of these rivers. The chloride levels near the mouth of the Herring River and Fresh Brook indicate the tidal influences that create estuarine environments (see Section IV.B.6 for more information). The mildly brackish conditions (slightly elevated chloride and total dissolved solid levels and high specific conductivity) in upper reaches of the Herring and Pamet Rivers (at and east of Route 6) may reflect tidal influences or some other source of salt contamination.

The coliform levels in the Pamet and Herring Rivers are higher than expected. The water quality of the Pamet River may be influenced by a nearby poultry farm (DWPC, 1976 p. 22-23).

The pH of the surface water is another area of interest due to the recently recognized acid rain problem in the Northeast. Data on the pH of the surface freshwater bodies is included in the Appendices G.3. and H (for more information on Acid Rain see Section IV.B.7.)

There is currently no information available on water quality in the marshes, bogs or swamps.

Groundwater Quality

The quality of groundwater depends on the chemical nature of groundwater recharge and the interactions with the land and water surfaces, and the soil as the water percolates to the water table. The natural recharge on the Cape is from precipitation. (There are also some small sources of artificial recharge on the outer Cape such as on-site septic systems and discharges to the ground water from wastewater treatment facilities (see Figures 6-9) (DWPC, 1978).

The data on groundwater quality on the outer Cape are from public water supplies, private wells and U.S. Geological Survey wells (see Appendix I) (CCPEDC, 1978a; DEQE, 1976; USGS, 1979). There are no water quality standards for groundwater, however, comparison can be made between the data and the expected natural background levels and with the drinking water standards and recommended limits for constituents of drinking water standards and recommended limits for constituents of drinking water (see Appendix F) (U.S. Environmental Protection Agency,1975 1976, 1977 and 1979). These comparisons indicate that the groundwater on outer Cape Cod is generally of high quality (CCPEDC, 1978a; USGS, 1979; DEQE, 1976). The most frequently encountered water quality problems are salt (sodium or chloride levels), nitrogen (as nitrate), iron, and manganese (CCPEDC, 1978a; USGS, 1979) (see Appendix I). Although iron, manganese and salt all do occur naturally on the outer Cape, elevated levels of these substances and others (such as nitrate), may indicate deterioration of water quality from human activities (see Section IV.B.2.) Since the quality of groundwater recharge is influenced by land use, the groundwater on Cape Cod is "susceptible to degradation from... sources such as ... solid-waste sanitary landfills, septage and liquid disposal sites (seepage pits or basins), dredging dumps, deicing salt-storage facilities, oil (hydrocarbon) storage areas and spills ... septic systems, urban runoff, highway runoff, [insecticide or herbicide use] and agricultural and lawn fertilizers" (USGS, 1979, p. 11). Consequently, land use management becomes important in preserving groundwater quality.

The U.S. Geological Survey has also analyzed some well samples for insecticides, herbicides and heavy metals. There was no evidence of contamination in any of the three wells tested on the outer Cape (USGS, 1979).

b) Coastal Water Quality

The Massachusetts Water Quality Standards of 1978 designate all outer Cape coastal waters as "SA" (see Appendix F). Water meeting this standard is suitable for "protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas' (Commonwealth of Massachusetts, Water Resources Commission, 1978).

In 1976, a survey of water quality in coastal areas of Cape Cod by the Massachusetts Division of Water Pollution Control (DWPC) revealed that the marine waters off Cape Cod are some of the highest quality waters in the state (DWPC, 1976, 1977 and 1978). Only a few areas on the outer Cape were in violation of the state water quality standards and these violations were mostly due to elevated levels of coliform bacteria (see DWPC, 1976 and 1977; CCPEDC, 1978a; Dunn, DEQE, written comm., 1980). The Provincetown and Wellfleet Harbors (segments 78 and 80) have some water quality problems (Dunn, DEQE, written comm., 1980). The data for the stations in these segments within the Seashore indicate that the quality problems apparently have not extended into the park (see Appendix J). There are presently no water pollution discharges to coastal waters on the outer Cape (DWPC, 1976 and 1978). It is unlikely any new discharges will be permitted due to the Natural Resource Waters designation and the presence of the Cape Cod Ocean Sanctuary.

Another indication of coastal water quality is the current status of the shellfish areas closures due to quality problems. There are almost 40,000 acres of potential shellfish areas on the outer Cape (acreage of coastal area from mean high tide to a 20-foot depth). In spring of 1980, only 142 acres were closed to shellfishing due to bacterial contamination (some acres within Provincetown Harbor, Wellfleet Harbor and Frost Fish Creek in Orleans) (see Appendix K) (Shellfish Sanitation Program, DEQE, pers. comm., 1980). Of these 40,000 acres, approximately 4,000 acres were considered "productive" in 1977 (Division of Marine Fisheries, 1977 cited in CCPEDC, 1978a p. 3-40). Almost 2% of the "productive" shellfish areas on the outer Cape were closed during that year (see Appendix K).

Occasionally additional areas are closed to shellfish harvesting due to red tide or oil pollution. Red tide is due to the occurrence of a marine dinoflagellate *(Gonyaulax tamarensis)* that produces a potent toxin that is accumulated by filter-feeding shellfish. In large numbers, the dinoflagelletes may cause Paralytic Shellfish Poisoning in humans due to consumption of contaminated shellfish. Red tide was first recorded in Massachusetts in the fall of 1972 (Bicknell and Collins, 1972). Since that time, there have been instances of red tide shellfish contamination in the spring or the fall or both on the outer Cape in two outer Cape communities, Eastham and Orleans.

The Nauset Bay area, in particular in Mill and Salt Ponds, has experienced repeated annual closures (Orphanos, DEQE, pers. comm., 1980).

Twice during the last three years, oil from cargo vessels washed up on the shores of outer Cape Cod (see Table 10). The oil from two other freighter accidents did not come ashore due to the fortuitous occurence of seasonal and climatic factors. The impact from these spills on the outer Cape's marine resources has received only limited assessment. However, the existing information on the toxicity of various types of oil does indicate the potentially serious threat of hydrocarbon contamination to marine water resources.

5. Water Quantity

Direct measurements plus estimates of other variables allow approximations of the flows among the various major components of the local hydrologic cycle (refer to Figure 4). On Cape Cod, the major components of the hydrologic cycle are precipitation, groundwater, the associated surface waters, and the coastal waters. There is a dynamic equilibrium established between recharge to the aquifer from precipitation that is balanced by discharge from the aquifer to streams, wetlands and the ocean.

Precipitation on the outer Cape (data from Provincetown station) averages around 40 inches per year with a minimum of 22.93" and a maximum of 58.20" observed over a period of 82 years (USACE, 1979). The monthly precipitation generally varies between two and four inches. The lowest rainfall is generally in the summer between May and August, with June and July usually the driest months (see Appendix L).

Annual evapotranspiration (water re-entering the atmosphere via evaporation and transpiration from plants) on the outer Cape has been estimated to be approximately 25-26 inches (Strahler, 1972; LeBlanc, USGS, written comm., 1980). Monthly estimates vary from zero in the winter months to a maximum of 5.3 inches in summer months (see Appendix M).

Figure 21 illustrates the relative magnitude of precipitation and evapotranspiration in the two distinct periods of an average year. The estimates for monthly evapotranspiration are greater than the average monthly precipitation between May and August. This difference creates a moisture deficit in the soil during the summer that is replenished in the fall months. Between September and April, when precipitation is greater than evapotranspiration, rain infiltrates and replenishes the soil moisture and raises the water table. It is estimated that on Cape Cod, it requires approximately four inches of precipitation to replenish the soil moisture deficit in the fall before the water table is replenished (Strahler, 1972; LeBlanc, written comm., 1980).

Estimates of annual recharge to the aquifer can be made by the Thornthwaite method (Thornthwaite and Mather, 1957). Annual recharge for the outer Cape has been estimated to be between 17 and 18 inches per year

Table X Oil Spills Near the Outer Cape, 1976 - 1979*

YEAR	SOURCE OF SPILL	COMMENTS ON THE SPILL
1976-1977	Sinking of the *Argo Merchant*; 30 miles off Nantucket	There was no land impact from this spill. The oil came within 30 miles of Chatham but due to the wind direction, the No. 6 fuel oil moved out to sea.
1977	Sinking of the *Grand Zenith*	Tar balls (approximately 4,000 gallons of No. 6 fuel oil) on beaches of outer Cape ocean coast from Race Point (Provincetown to Nauset Beach)
1978	Spillage from *Global Hope*; February 20, 1978	Spillage occurred in Salem Sound but the oil was carried to Cape Cod Bay by severe storm weather. Oil was observed on coastal areas from Brewster to Truro with heavy oil on beaches of Great Island in Wellfleet.
1979	Sinking of the *Regal Sword*; June 18, 1979; 30 miles southeast of Chatham	Some tar balls were found on Martha's Vineyard and Nantucket.

* Data from Division of Water Pollution Control and Division of Marine Fisheries recores.

(see Appendix M) (Strahler, 1972; LeBlanc, USGS, written comm., 1980). This natural amount of recharge is necessary to retain the historic shape of the fresh groundwater lenses and the amount of discharge to adjacent water resources.

The yearly and seasonal variations in groundwater recharge from precipitation affect the size and shape of the aquifer sub-basin. The elevation of the water table and pond surface levels vary yearly and seasonally in response to variations in precipitation and groundwater recharge. The hydrographs in Appendix N graphically illustrate the fluctuation in water table elevation over several years. More detailed information on water table elevations in each basin and surface pond level elevations over several years and throughout each year is available from U.S. Geological Survey and in the North Atlantic Regional Office of the National Park Service. Movement of the fresh-saltwater transition zone in response to changes in recharge has not been observed on Cape Cod, although this phenomenon may occur (LeBlanc, USGS, written comm., 1980). Data on the depths to the fresh-saltwater transition zone on the outer Cape are given in Appendix O and roughly indicated in Figure 4.

Surface water flow and groundwater seepage into the coastal areas are two other sources of exchange between components of the hydrologic cycle. Surface runoff on the Cape is minimal due to porous soils. Data on the flow of the Herring River indicate the generally placid, low-flow conditions of the largest river within the Seashore boundaries (see Appendix P). The surface water flow is so limited that in calculations of a water budget for outer Cape Cod, surface runoff is usually considered negligible (Strahler, 1972; LeBlanc, written comm., 1980).

Although not a part of the water budget for Cape Cod, it is important to point out that since the retreat of the glaciers from this area (approximately 12,000 years ago), sea level has been rising at the rate of approximately 1 - 1 1/2 feet per century (USACE, 1979). Over the period of record, there are indications that the rate of sea level rise is accelerating. It has been estimated that over the next 50 years, mean sea level will rise between 1/2 and 1 1/2 feet above the present mean (USACE, 1979).

Figure 21.

Yearly distribution of precipitation and evapotranspiration based on 12 years of records from the Provincetown Station, 1931-1952.

(Modified from Strahler, 1972.)

6. Floodplain Management and Wetland Protection

With recognition of the ecological as well as economic value of wetlands and floodplains, various legal mechanisms for protecting these valuable areas have been instituted. The National Park Service is responsible for implementing the Executive Orders on Floodplain Management and Wetland Protection (Executive Order Numbers 11988 and 11990). The implementation guidelines require identification of the floodplain and wetland areas within Cape Cod National Seashore and an inventory of the existing and proposed structures or facilities (other human development in these areas).

The location of wetlands and floodplains within the Seashore are indicated in Figures 11-15 and 16-20, respectively.* The only existing National Park Service-managed structures and facilities located in either of these sensitive water resources areas are listed in Table XI. There is no proposed development by the Park in wetland areas or in the 100-year floodplain. There are other structures located in the 100-year floodplain but not managed by the Park Service. A few of these structures are indicated on Figures 16-20. In particular, there are three dikes located in the outer Cape 100-year floodplain that serve as structural flood control measures.

*(The maps indicating the 500-year Floodplain are not yet available for the entire outer Cape.)

Table XI Structures and Facilities Located within Wetlands or On the 100-Year Floodplain and Managed by the National Park Service

Structure or Facility	Location	Comments
Foot Trails	Wellfleet and Orleans Quadrangle	
Bike Trails	Provincetown, North Truro, and Orleans Quadrangle	
Jeep Trails	Provincetown, North Truro, Wellfleet and Orleans Quadrangle	
Sand Roads	Wellfleet and Orleans Quadrangle	
Paved Roads:		
Provincelands Road	Provincetown Quadrangle	
Race Point Road	Provincetown Quadrangle	
High Head Road (part)	North Truro Quadrangle	
Pamet Point Road	Wellfleet Quadrangle	
Cranberry Bog House	North Truro Quadrangle (see Figure 17)	Used in the park's interpretive program and nominated to the Register of Historic Structures
Boat House (on Salt Pond)	Orleans Quadrangle (see Figure 19)	Currently under Special Use Permit to the Town of Orleans.
17 Structures	Orleans Quadrangle (see Figure 19)	One structure is under Special Use Permit to the Town of Chatham. 16 structures will be occupied by the private owners until the year 2000 or 2005.

* Due to lack of a complete set of maps for the 500-year floodplain on the outer Cape, only the 100-year floodplain was mapped and inventoried for structures and facilities.

7. Water Resources Monitoring

The monitoring of water quality and quantity of the various water resources is performed by a number of groups.

Fresh Surface Water Monitoring

The County Health Department does water quality testing for pond water samples at the request of local Boards of Health. The National Park Service periodically samples certain kettle ponds within Cape Cod National Seashore. The Massachusetts Division of Water Pollution Control (DWPC) performs Lake Classification surveys that investigate the water quality of Massachusetts lakes and ponds; however, no outer Cape ponds have yet been studied by this program. In the summer of 1980, under Section 314 of the Federal Clean Water Act, the DWPC conducted a Lake Classification Program Study on several Cape Cod ponds.

Groundwater Monitoring

The Division of Water Supply within the Massachusetts Department of Environmental Quality Engineering (DEQE) is responsible for sampling water quality of municipal supplies in compliance with the Federal Safe Drinking Water Act and Massachusetts laws. There are many types of water quality analyses performed by the state and the sampling schedule for different analyses varies. The local communities are responsible for the bacteriological analyses of these municipal water supplies which are required by law. The Barnstable County Board of Health tests the weekly municipal water samples for the towns. These data are sent to the DEQE and reviewed by the Division of Water Supply for compliance with federal and state drinking water standards. The County laboratory also tests private well samples for bacteria and for some chemical parameters. Similarly, the National Park Service monitors the water systems maintained for public use within the Seashore. The U.S. Geological Survey does some water quality analysis (chloride levels and specific conductivity) on well samples from seven zone of transition well sites, two of which are on the outer Cape.

Data on water table and surface water elevations and on the fresh-saltwater transition zone are collected from a variety of sources and compiled by U.S. Geological Survey. The CCPEDC samples water levels in 60 wells, 40 per month. Monthly, the National Park Service monitors wells in Truro and around Gull Pond for water table elevations. The Association for the Preservation of Cape Cod (APCC) monitors surface water levels in ten ponds every month. All these agencies forward the data to the U.S. Geological Survey where the information is stored on a computer. The U.S. Geological Survey monitors the fresh-saltwater transition zone by sampling

deep wells every six months at sites on the outer Cape. The National Park Service in cooperation with the U.S. Geological Survey, monitors the zone of transition from a deep well in North Truro every two weeks. Most observations on water table elevation date from the early 60s; the data on the zone of transition are from the mid-70s.

Coastal Water Monitoring

The DEQE's Division of Water Pollution Control (DWPC) performs bacterial and chemical analyses of coastal waters at five-year intervals. The next sampling is planned for 1981. The DEQE regularly monitors shellfish areas for bacterial contamination and the presence of red tide. The Barnstable County Health Department does bacterial testing for recreational and shellfish areas at the request of the towns.

IV. Water Resources Problems and Assessment of Proposed Management Alternatives

A. Introduction

Water resources management from the perspective of the National Park Service requires protection of water quality and quantity within the park's ecosystems. The following sections describe several current or potential water resources problems within Cape Cod National Seashore. After each problem statement (Section A), there is a brief description of the water resources that are affected, the nature of the impact, a brief history of the problem, and the current status of the situation (in Section B).

Political boundaries do not coincide with ecosystem boundaries and so influences on a particular water resource may come from beyond the boundaries and the immediate jurisdiction of the Park Service. Therefore, a section (C) discusses the existing land ownership and jurisdiction if appropriate, as well as any laws and policies pertinent to each water resources problem. The established jurisdiction may lead to a cooperative management program between the National Park Service and other agencies or individuals to successfully address the water resources problem.

The next section (D), Alternatives for Management, presents several possible management actions, each representing a management strategy to address the problem. All alternatives listed are consistent with the National Park Service Management policies and Water Resources Management objectives for Cape Cod National Seashore (see Section II.B.). The anticipated impacts of each alternative and the preferred alternative is also discussed in this section.

The last section (E), discusses the research needed to provide additional data ~~is needed~~ prior to initiation of any management actions. The research needs will be prioritized by the park.

B. Water Resources Problem Descriptions and Management Alternatives

1. Management of Groundwater Quantity

A) Problem Statement

The groundwater of Cape Cod directly supports the majority of the Cape's inland water resources and influences estuarine ecosystems by coastal groundwater seepage. Since groundwater provides the sole source of drinking water on the outer Cape, the rapid growth in the residential population and tourism on the Cape, has resulted in a related increase in the withdrawal of groundwater. Groundwater withdrawal creates changes in the water balance and the rate and pattern of groundwater flow that can alter a groundwater lens and adversely affect groundwater-dependent ecosystems. Because of the hydrology of the aquifer sub-basins, groundwater

withdrawal from park land, as well as from non-park land within or adjacent to the park, may impact the groundwater sub-basins and dependent ecosystems within the park. Impacts from groundwater withdrawal depend on the location of the well, the soil characteristics, the amount and rate of removal, and whether or not the water is returned to the basin. Artificial groundwater recharge may lessen the impact of water removal, but may affect the quality of the water.

At present groundwater withdrawal, in most cases, is not regulated by state law. Massachusetts groundwater law confers a basically unlimited right to extraction of groundwater with land ownership.

Cape Cod National Seashore was established to preserve the natural ecosystems and cultural resources within its boundaries. Thus, removal of resources and any subsequent damage to the resources is contrary to the purposes for which the park was created. Laws regulating the National Park Service allow sale and removal of park resources only under specific conditions.

The Park Service policies and legal constraints on removal and consumptive use of resources and the Cape's hydrological limitations, create a potential conflict with the projected increased demand for use of groundwater resources.

B) Resource Description and Problem History

The size and shape of each aquifer sub-basin on the Cape is a result of a dynamic equilibrium established in response to the water budget for the area (see section III.B.5.) Water entering the basin as recharge is balanced in amount with the discharge to the ocean or freshwater ecosystems and results in the size and shape of the basin. Any changes in the water balance of the aquifer will result in changes in the groundwater lens. The only source of drinking water on the outer Cape is groundwater and therefore providing human water needs requires removal of groundwater from the aquifer.

The environmental impacts of groundwater withdrawal for water supply depend on the response of the basin to pumping and the type of wastewater disposal system. The type of disposal system also influences groundwater quality. Pumping groundwater causes a local lowering of the water table in the immediate vicinity of the well which is called drawdown (see Figure 22) (Strahler, 1972; CCPEDC, 1978a; U.S. Geological Survey, written comm., 1979). The amount of drawdown and the size of the area affected depend on a variety of engineering and geohydrological factors including the rate of pumping, depth and screening of the well, and the type and characteristics of the soil in the area. If there is a high rate of pumping or if there are several wells located close together, there may be a general lowering of the water table in the area. A deep well with a high rate of pumping may also cause saltwater to be drawn into the well from the base of the aquifer, a phenomenon called upconing (see Figure 22) (Strahler, 1972). Withdrawal of groundwater may change groundwater flow patterns in an

area and affect the flow of ground water to the other water resources such as wetlands as well as impact the quality of the groundwater. A comparison of the groundwater flow patterns in Figure 5 and Figure 22 illustrates the alteration in flow patterns that can result from groundwater withdrawal.

The type of wastewater disposal system determines whether or not the groundwater is returned to the basin from which it was removed and thus affects the quantity of water as well as the quality. Several towns (part of Truro, Wellfleet and Eastham) on the outer Cape have private, individual wells and on-site septic systems so that the groundwater pumped for domestic use, re-enters the basin near where it was withdrawn, even though the water quality may be altered by human use. Municipal wells with larger pumping rates can have more of an impact on the local water table. The towns on the outer Cape served by municipal wells (Provincetown, part of Truro, Orleans and Chatham) in most cases also have on-site septic systems. (For the location of the existing municipal wells on the outer Cape, see Figures 7-10). Combining septic systems and municipal supply transfers groundwater to different sections of the basin. This water transfer creats an artificial source of recharge, which also changes the hydrologic balance and can raise (mound) the water table in the area of water recharge (CCPEDC, 1978a). If the municipal supply for a town is located in a different basin than the on-site septic systems, such as in Provincetown and part of Truro, then the groundwater withdrawn is never returned to the original basin. Such an interbasin transfer of water affects the hydrologic balance of each basin; there is water loss from one basin (one type of consumptive use) and artificial recharge to the other. Irretrievable loss of fresh groundwater also results from sewer systems with ocean outfalls, such as experienced on Long Island (Franke and McClymonds, 1972). No ocean outfalls currently exist on the outer Cape.

An interbasin transfer of groundwater impacts an aquifer in a manner similar to a drought. When recharge to the basin is reduced, due to a dry year or from human use, the size of the lens decreases both laterally and vertically. The water table elevation also decreases which could impact ponds, streams and wetlands that on the Cape are surface exposure of the water table and depend on groundwater as a water source. The sub-basin may become shallower, and saltwater may intrude from below the aquifer into deep wells (upconing). A saltwater wedge may move inland along the coast which may result in saltwater intrusion into the coastal wells. The discharge to the coastal water may be reduced so that the salinity of estuarine environment is altered. The increased salinity may be harmful to many species dependent on the estuaries for part of their life cycle.

Current Status of Water Supply Problems on the Outer Cape

Currently on the outer Cape, the only town with an immediate water supply problem is Provincetown. Provincetown, located on the tip of Cape Cod, is underlain by a shallow groundwater sub-basin that generally has high iron and manganese levels and must be treated to be potable (Whitman and Howard, 1973). Since the late 1960's, Provincetown has been searching for a new well site to meet projected water demands.

Figure 22. Schematic Representation of the Impacts on the Groundwater Lens from Groundwater Withdrawal.

The "a" line indicates the upper and lower boundaries of the freshwater lens (i.e. the water table and the fresh-saltwater transition zone) with no groundwater withdrawal. The "b" line indicates the boundaries of the lens after groundwater withdrawal from the well. The vertical scale is greatly exaggerated for clarity. (Modified from Strahler, 1972)

In December 1977, gasoline leakage from an underground storage tank threatened to contaminate Provincetown's major water source (South Hollow Wellfield, North Truro) and necessitated its closing. Reclamation of this wellfield is still in progress (Camp, Dresser and McKee, 1980). To provide Provincetown water during this emergency (prior to reclamation of the South Hollow Wellfield), two temporary well sites were put into operation in the spring of 1978. One is located on the North Truro Air Force Base, the other is located within the National Park Service boundaries on park land in North Truro (referred to as Well Site #4) (see Figure 8). Permission for such an emergency request was granted by the Park Service according to National Park Service General Authorities Act (P.L. 91-383, as amended by P.L. 94-458), the Park Service required Provincetown to demonstrate (with a technical report) that the town had no feasible alternatives for this short-term, emergency water supply. The technical report, prepared by the firm of Camp, Dresser and McKee under contract to the town, recommended the two emergency sites which were eventually used (Camp, Dresser and McKee, 1978). National Park Service review of the report found an emergency did exist and granted a short term permit. The North Truro Air Force base also granted Provincetown permission to use their well.

Since 1978, these two temporary water supplies have been in use during the tourist season (summers of 1978, 1979 and 1980), since the reclamation of the South Hollow Wellfield has not been completed. Knowles Crossing, Provincetown's other municipal wellfield is sufficient for the town's water demand in the winter.

Concurrently, Provincetown is still interested in a new permanent wellfield and has employed Camp, Dresser and McKee to evaluate the future need for an additional water supply and if necessary, to evaluate possible sites; this report will be available in the near future.

C) Information for Management

Massachusetts groundwater law, based on court decisions and not on statute, follows the English rule of absolute ownership of groundwater, sometimes referred to as "land ownership rights" (Todd, 1967; Commonwealth of Massachusetts, Division of Water Resources, 1979). The "property rights to the extraction of groundwater are attained through ownership of the overlying land." (Commonwealth of Massachusetts, Division of Water Resources, 1979, p. 63). This law does not establish a legal framework for limiting groundwater withdrawal based on resource capacity or for allocating use of this resource.

The main purpose of a national park is "to conserve the scenery and the natural and historic objects" (see Appendix C) (National Park Service Organic Act of 1916, 39 Stat. 535). Development that would be "incompatible with the preservation of the unique flora and fauna on the physiographic conditions......" is prohibited by the legislation that established Cape Cod National Seashore (see Appendix D) (P.L. 87-126). These laws do not provide a basis for removal of any park resources.

The only legislative authority that does specifically address consideration of removal and sale of any national park resources is the Park Service General Authorities Act (see Appendix Q) (P.L. 91-383, as amended by P.L. 94-458). However, this law specifies explicit limitations on removal and sale or lease of park resources. Under this legislation, park water resources can be sold or leased, only if the following conditions are met: (1) the activity cannot "jeopardize or unduly interfere with the primary natural or historic resource of the area involved....", (2) the party contracting to acquire the water must provide public accomodations or services in the immediate vicinity of the national park to persons visiting the area, (3) the party contracting to acquire the water must demonstrate that no reasonable alternative to the proposed activity exist to acquire the necessary water. (Regional Solicitor, DOI, written comm., 17 January 1980). The requested information action is reviewed by the National Park Service and may be reviewed by a Congressional Committee prior to any decision for sale of a resource.

In addition, if any activities on park or adjacent land were found to be causing damage to the water or related resources of the Seashore so that the purposes of the park were being disrupted, the Property Clause of the U.S. Constitution may provide for legal intervention in the activities causing the damage (Regional Solicitor, DOI, written comm., 31 March 1977).

Any water rights conveyance by a national park would probably be considered a "major federal action significantly affecting the quality of the human environment" and if so, the National Environmental Policy Act (NEPA) (P.L. 91-190) requirements would apply. The NEPA requirements include preparation of an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) which would provide additional relevant information pertinent to the conditions of P.L. 91-383, as amended.

These laws and National Park Service policies are in general agreement with the Massachusetts Coastal Zone Management (CZM) policies. Although no policy directly addresses the issue of groundwater quantity on the outer Cape, policies (1), (3) and (34) closely relate (Commonwealth of Massachusetts, CZM Program, 1978). Adverse effects of groundwater (particularly consumptive) withdrawal may alter the flow of freshwater to wetlands and estuaries that are ecologically significant areas. To maintain long term water quality (Policies 3 and 34), adequate protection of the groundwater quantity in the aquifer basins on Cape Cod is essential (Commonwealth of Massachusetts, CZM Program, 1978). For further information on compliance with other laws and policies see Section VI.

D) Alternatives for Management

1. No additional management action.

The National Park Service would not initiate any additional management actions. However, all current water quantity management and compliance with all legal requirements would continue. In particular, a thorough evaluation of requests for removal of groundwater would be

required under current law (P.L. 91-383, as amended).

Impacts

Thorough review of resource removal requests (in compliance with existing laws) is conducted to assure protection of the water resources. Such detailed evaluation of a technically complex and perhaps controversial water supply request may require the assistance of other government agencies and/or private consultants for the most comprehensive and unbiased review. This technical assistance will take time and require funding. The expenses incurred may be borne at least partially by the agent making the resource request. Financial costs, delays in time, and the potential for denial of resource requests, all may have adverse socioeconomic impacts on the agent making the request. There may be mitigation measures the Park Service could take in each particular situation that would be consistent with the legal constraints.

This alternative does not address changing current water consumption.

Preferred Alternative 2. Develope a comprehensive water conservation program for Cape Cod National Seashore.

This alternative would be in addition to all current water quantity management and legal compliance in Alternative #1.

A Water Conservation Program would include but not be limited to:

a) Installation of water saving devices in all current and future Park Service facilities.

Mechanical water saving devices for faucets and toilets are readily available and easily installed. Wherever feasible, dry toilets would be installed at facilities and at recreational areas with heavy use. Use of dry toilets reduces water consumption and reduces groundwater contamination and so is appropriate in areas such as Cape Cod.

b) Education and interpretation through personnel, signs, displays and publications.

Water supply from both a natural (geological and ecological) as well as a cultural perspective would be the subject of more park interpretive activities. This alternative would encompass a variety of activities but could include a Visitor Center display, a pamphlet, a newspaper article, an interpretive program on the Cape's hydrological system and signs illustrating the water-saving devices installed. During seasonal training sessions for both interpreters and rangers, the outer Cape's water supply, its natural and cultural history and its current status, would be thoroughly discussed.

c) Co-sponsor meetings open to the public on institutional options for groundwater management on Cape Cod.

The meeting(s) would serve as a forum of the need and alternatives for groundwater management for including presentations on current and other feasible institutional options and legal frameworks. There has been previous discussion of a Cape Regional Water Authority (Frimpter, 1973; CCPEDC, 1978b; Regional Director, NPS, written comm., 7 Feburary 1979). Other institutional possibilities include formation of groundwater basin associations or water districts.

Representatives from all Cape communities (both town government and citizen representatives), state agencies involved with water quality and supply, Barnstable County, and U.S. Geological Survey would be invited. The CCPEDC would be asked to co-sponsor the meetings due to their involvement with the water supply and water quality issue.

Impacts

A public and Park Service personnel awareness of water conservation as well as the ecological implications of water use on the outer Cape, and a reduction in water use may result. Reduced pumping would decrease the possibility of adverse environmental impacts that may be associated with well sites. Reduced water use also enhances groundwater quality. Reduced flow through septic systems can increase wastewater retention time in the septic tank that allows more complete bacterial digestion of wastes and produces an improved quality of effluent that is returned to the water table. Lower flow may also extend the length of time a leach facility operates efficiently (CCPEDC, 1978b). A water conservation program is a positive and environmentally sound way of responding to a resource limitation, since successful water conservation programs can avert expensive and ecologically damaging water projects.

There would be a cost for purchasing the water saving devices. Personnel time for installation and maintenance would also be required.

Focusing certain interpretive activities on the water supply issue without an increase in the interpretive budget means coverage of other topics would be reduced or eliminated.

The meeting(s) on institutional options for groundwater management on the Cape would provide a forum for discussion of the current Provincetown situation as well as responses to other future Cape water supply problems. The water supply issue is certainly important and there is a need for water resources planning to prevent quality deterioration and possible severe damage to the groundwater. By coordinating or co-sponsoring these meetings, the Park Service may be able to facilitate some long-term groundwater resources planning and policy formation for Cape Cod.

E) Proposed Research

As mentioned previously, the U.S. Geological Survey has been studying the Cape Cod groundwater aquifer and will receive additional financial support to continue this work. In addition, research on the

ecosystems associated closely with the groundwater aquifer will be done in order to adequately assess environmental impacts for any proposed groundwater removal.

2. Management of Groundwater Quality

A) Problem Statement

Groundwater quality is affected by surface and subsurface land use, since precipitation that percolates through the soil is the source of the groundwater on Cape Cod. Maintaining the natural high quality of the groundwater is a resources management objective of the Seashore as well as an economic and public health concern. An expanding resident population along with increases in tourism result in increases in the leval of activities and the types of land use that may have adverse impacts on the quality of groundwater in natural ecosystems as well as drinking water supplies. Certain activities and land use within and adjacent to the National Seashore pose threats to groundwater quality.

B) Resource Description and Problem History

A description of the groundwater resource can be found in the previous sections on groundwater (Section III.A.5. and Section IV. B.1.).

The aquifer sub-basins on outer Cape Cod are maintained by the natural recharge from precipitation and a limited amount of artificial recharge from septic systems and wastewater treatment facilities. Consequently, the quality of the groundwater is influenced directly by the quality of the recharge water and by the chemical changes in the recharge water as it passes through the soil.

Many possible sources of groundwater contamination have been identified in previous studies (Frimpter, 1973; CCPEDC, 1978a). Septic tanks and cesspolls use of septic system cleaners; sanitary landfills; urban and highway runoff; leaks, spills and disposal from hazardous chemical storage tanks; storage and use of road salt; storage and use of herbicides, pesticides and fertilizers; and consumptive and/or excessive groundwater withdrawal resulting in salt-water intrusion (from the sides or bottom of the aquifer) have all been found to potentially cause groundwater quality problems.

Any source of groundwater contamination from surface or subsurface land use may develop a pollution plume extending from the source that is spread by groundwater flow (see Figure 23). Groundwater withdrawal can shift flow patterns and therefore alter the areas impacted by pollution plumes. Groundwater does move very slowly, so detection of contamination may be difficult. There is a limited amount of mixing of the groundwater within each basin so the contamination plume may remain stratified and concentrated. Even so, the pattern and rate of flow for contamination plumes does vary depending on the chemical constituents of the plume (Miller, pers. comm., 1980).

The majority (approximately 90%) of the population on the Cape uses on-site wastewater disposal systems, either cesspools or septic systems (CCPEDC, 1978a). Park and private residences within the Seashore boundaries are no exception to this. These on-site systems and the disposal of the septage from septic systems are both threats to groundwater quality. In addition, use of septic system cleaners containing toxic organic solvents, can lead to chemical contamination of the groundwater and is not necessary for proper system maintenance.

Disposal of solid waste in sanitary landfills also poses a threat to groundwater quality if leachate plumes form below landfills. The characteristics of the landfill cover material, (required in order to prevent leaching), the characteristics of the soil, the type of solid waste, the chemical constituents of the leachate, the depth to the water table, and the pattern of groundwater flow all influence the severity of the problem in a particular area. The landfill locations are shown on Figures 7-10. The CCPEDC studied the leachate from a landfill in Dennis and found chemical changes in the adjacent groundwater (CCPEDC, 1978a).

Storage of chemicals, including hazardous materials, on the outer Cape is limited primarily to gasoline, road salt, pesticide and herbicide storage. Leakage of stored chemicals has in the past, caused closure of water supply wells in Provincetown and Yarmouth (Special Legislative Commission on Water Supply, 1979).

Runoff including both urban and highway runoff, can create groundwater contamination problems. Cyclic hydrocarbons and salt were found in highway runoff on the Cape (CCPEDC, 1978a). Use of salt on roads in the winter and leachate from salt storage both can be sources of groundwater contamination. Similarly, both storage and use of herbicides and pesticides can contaminate groundwater. Fertilizers that enter the groundwater can cause eutrophication problems in groundwater-fed water resources.

Shifts in the size and shape of the fresh groundwater lens caused by lack of precipitation or withdrawal of groundwater can result in intrusion of seawater along the coast and from beneath the aquifer. The increased salinity causes alteration of freshwater biological communities and can cause pollution of drinking water.

C) Background Information for Management

Cape Cod National Seashore lies within the state-designated 208 water quality planning area (section 208 of the Clean Water Act). In 1978, a Water Quality Management Plan/EIS for Cape Cod was prepared by CCPEDC. The 208 Plan addressed the issue of preserving groundwater quality and identified many of the sources which threaten water quality (CCPEDC, 1978 a and b). The Cape Cod Planning and Economic Development Commission has been working with the State and local towns to implement many of the recommendations of this study. Some Cape towns have initiated wastewater treatment planning.

Figure 23

Schematic Representation of Groundwater Pollution from Surface and Subsurface Land Use. (Modified from Strahler, 1972).

Title 5 of the State Environmental Code written by the Department of Environmental Quality Engineering (DEQE), (November 1975, effective July 1977) governs subsurface disposal of sanitary sewage including septage from septic systems. Local Boards of Health may adopt standards and regulations for siting new septic systems stricter than those of the State. Some outer Cape towns have done this (CCPEDC, written comm., 1980). The local Boards of Health must also issue permits for each new disposal system, and notify DEQE when the permit is for a large recreational facility or industry.

Septage from septic systems may be disposed of only by a handler licensed by the Board of Health on a site approved by DEQE. The type and location of septage disposal for each outer Cape town and Cape Cod National Seashore facilities is given in Table XII and the landfill locations are shown on Figures 7-10. New Massachusetts regulations for sanitary landfills are being forumulated by DEQE and will be in effect in the fall of 1980.

Table XII SEPTAGE DISPOSAL SITES ON OUTER CAPE COD*

COMMUNITY	TYPE & LOCATION OF SEPTAGE DISPOSAL
Provincetown	Open pit at landfill
Truro	Open pit at landfill
Wellfleet	Open pit at landfill
Eastham	Open pit at landfill
Orleans	Open pit at landfill
Chatham	Wastewater Treatment Plant (10,000 gpd capacity since Feburary 1, 1979). Open pit at landfill for additional flows.

* From CCPEDC, written comm., 1980.

Groundwater and surface water pollution by leachate is prohibited by Massachusetts state law (Mass G.L. Chapter 21, section 42)

> "...Any person who directly or indirectly
> allows the discharge of any pollutant
> into the waters of the Commonwealth
> except in conformity with a permit
> ... shall be punished by fine."

"Waters of the Commonwealth" as defined in the legislation, includes groundwater.

Ultimately, if park water resources, such as groundwater, were being polluted to the extent that the purposes of the National Park were disrupted, then the Property Clause of the U.S. Constitution may provide a means for legal intervention in the activities causing the deterioration of the resource.

Park Service policies and the Seashore's water resources management objectives require that the high quality of the groundwater resources be maintained. This goal is consistent with policies of the Massachusetts Coastal Zone Management Plan as well as the Cape Cod 208 Plan.

D) Alternatives for Management

1. No additional management action.

This alternative would provide no additional management actions by the National Park Service to ensure groundwater quality. However, all current management practices would continue in compliance with Park Service laws and policies.

The park has significantly reduced the amount of salt applied to park-maintained roads within the Seashore by using sand on roads in the winter. Only a small amount of salt is mixed with the sand to keep the sand from freezing. However, the park-maintained roads represent only a very small percentage of the roads within the park. At present, the Commonwealth of Massachusetts stores road salt within the park boundaries in North Truro in accordance with a Special Use Permit.

At present and more problematically, the Seashore presently operates on-site septic systems and cesspools in some residences and facilities and disposes of its septage and solid waste in the town landfills. Regular maintenance is done on all Park-operated septic systems and gasoline storage tanks.

Impacts from Alternative #1

The current groundwater management actions by the National Park Service reduce the pollution of groundwater as well as present possible additional pollution. However, there are groundwater pollution sources within and adjacent to the park boundary that are not addressed in this alternative. This alternative does not include comprehensive planning for groundwater quality protection.

2. Develop a Groundwater Quality Program for Cape Cod National Seashore.

This alternative would be in addition to all actions in Alternative #1.

A Groundwater Quality Program for all park areas and facilities would include but not be limited to the following actions:

a) Development of a park system for septage treatment and disposal.

The Seashore would investigate the methods available to the park for treatment and disposal of septage from Park Service residences and facilities.

b) Development of a park solid waste recycling center.

The Seashore would initiate a recycling program for the solid waste from Park Service residences and facilities.

c) Elimination or reduction of the use of pesticides and herbicides on park land.

The current Park Service use of pesticides and herbicides is restricted to developed areas within the park e.g., the Visitor Centers and Park Headquarters). All current or proposed future use would receive careful evaluation specifically in terms of the possible impact on groundwater quality.

d) Interpretation and education through personnel, signs, displays, and publications.

The Park Service would contribute to public awareness and understanding of the type and significance of groundwater contamination through the activities of the interpretive program such as pamphlets, interpretive programs, and displays.

e) Removal of park buildings from sensitive water resources areas.

The Park Service currently maintains some buildings (built previously by private owners on acquired property) with cesspools or septic systems, some of which are used by Park personnel. Those buildings adjacent to water resources that may be particularly sensitive to groundwater contamination would be vacated and removed.

Impacts from Alternative #2

Awareness by the public and Park Service personnel of the activities that can contaminate groundwater and the resulting adverse consequences may result from this Seashore program, and in particular from the educational and interpretive activities. Additional protection and perhaps in some cases restoration of groundwater quality may result from elimination or reduction of pollution from Park Service activities.

Many activities within the Park boundary with potential for groundwater contamination, are not under the Park's jurisdiction and will not be affected by this management alternative.

Septage treatment and disposal by the Park Service alone may not be the most economic and efficient method. The Cape Cod 208 Plan compared the costs of local and regional septage treatment facilities and found the regional facility to be most cost effective (CCPEDC, 1978a). Regional treatment and disposal would also limit the potential for the groundwater pollution to a single or small number of site(s). However, as the 208 Plan also points out, there would be increased transportation costs with regional treatment.

Preferred Alternative 3. Develop a Cooperative Groundwater Quality Program.

This alternative would be in addition to all actions in Alternative #1.

A Cooperative Groundwater Quality Program would include but not be limited to the following actions:

a) Cooperative with adjacent towns in planning for regional septage treatment and disposal.

Cape Cod National Seashore would join with local towns in planning (identifying and evaluating alternative methods) regional septage treatment and disposal. The 208 Plan mentioned some preliminary regional sites for the outer Cape (CCPEDC, 1978a).

b) Cooperate with local towns in solid waste recycling programs.

The park staff would increase their efforts to recycle solid waste from Park Service facilities. Many towns on the outer Cape already have ongoing recycling programs so the Park would contact the existing programs and enter into some cooperative agreement with these towns in solid waste recycling.

c) From a cooperative agreement with the Commonwealth of Massachusetts and with local communities to eliminate or reduce the present use of salt on roads within and adjacent to the Park boundary.

The State (Department of Public Works) and the towns are responsible for the majority of roads within the park boundary. In the winter, road salt is used to keep the roads clear of snow, however, use of salt on roads is another groundwater contamination source (CCPEDC, 1978; U.S. Geological Survey, 1979). Some efforts have been made by state agencies to reduce the amount of salt used on roads. Under this alternative, representatives from the Seashore would meet with representatives from the State and from town agencies who are responsible for road salting and draft an agreement on salt storage and use.

d) Form a Cooperative Agreement with the adjacent towns and agencies of the Commonwealth of Massachusetts including the Cape Cod Mosquito Control Project to eliminate or reduce the use of pesticides and herbicides within the park boundary.

To protect the groundwater quality, the Seashore would meet with representatives from these other agencies and draft an agreement on the application of pesticides and herbicides.

e) Interpretation and education through personnel, signs, displays, and publications.

The Park Service would contribute to public awareness and understanding of the nature and significance of groundwater contamination through the activities of the interpretive program such as pamphlets, interpretive programs and displays.

f) Removal of park buildings from sensitive water resources areas.

The Park Service currently maintains some buildings (built previously by private owners on property since acquired) some of which are used by Park personnel and have cesspools or septic systems. Those buildings adjacent to water resources that may be particularly sensitive to groundwater contamination would be vacated and removed.

<u>Impacts</u> from Alternative #3

As mentioned in the discussion of the impacts of Alternative #2, development of a regional septage treatment facility has been shown to be economically advantageous to several, small, individual facilities (CCPEDC, 1978a). As one generator septage waste on the Cape, the Park Service would be involved in cooperative planning for treatment and disposal of this waste.

Recycling of solid waste decreases the amount of solid waste disposed in landfills. Since leachate from landfills may be a source of groundwater contamination, a decrease in the amount of solid waste would decrease pollution of groundwater and increase the life span of the current landfills. There are long-term resource savings for everyone from recycling material. Recycling programs already exist in many of the towns on the outer Cape with which the park may be able to cooperate. Cooperation with the existing programs would probably be more economical than establishing a separate park program.

Elimination or reduction of the use of salt and chemicals within the park boundary by agencies other than the Park Service would reduce the potential for contamination of groundwater.

Other actions (such as option f) by the Park Service may also reduce the threat of groundwater contamination. Public and Park Service awareness of the potential and nature of groundwater contamination would result from interpretive and educational programs by the park.

E) Proposed Research

No research is currently proposed.

3. Management of Freshwater Kettle Ponds

A) Problem Statement

The kettle ponds of Cape Cod National Seashore are a unique and fragile resource of ecological, aesthetic and recreational value. In the past few years, the Park Service has conducted and coordinated research programs on the kettle ponds to investigate the status of pond water quality. These and other studies have indicated there are four major areas of concern for pond water quality: 1) excess nutrient addition (resulting in cultural eutrophication); (2) sediment addition from shoreline erosion; (3) possible public health hazards from bacterial contamination, and (4) possible chemical pollution.

B) Resource Description and Problem History

Cultural eutrophication is the term used to describe human-induced additions of nutrients in excess of their natural quantity and rate of availability. The kettle ponds on Cape Cod are fed and drained primarily by groundwater seepage, therefore the ponds flushing rates are slow and the ponds are susceptable to eutrophication and other contamination problems (Frimpter, 1973). An accelerated supply of plant nutrients results in deterioration of the pond as a recreational resource; the symptoms are usually a gradual increase in algae densities (with loss of water clarity), sudden algal population explosions (algal blooms) and a general increase of larger shoreline aquatic plants. Measurements of chlorophyll-a have been used as an indication of eutrophic status for several ponds within Cape Cod National Seashore (Soukup, 1977 and 1979) (see Appendix G.1). The algal biomass levels appear to indicate cultural eutrophication in several ponds, most notably Gull, and to a lesser extent Duck, Higgins, Ryder, Williams, and Great (Truro) Ponds (Soukup, 1977 and 1979; Ludlum, 1977).

a lack of

There are many environmental factors that determine levels of plant growth in a pond ecosystem; however, phosphorous may be a key element in limiting the natural level of freshwater productivity (Hutchinson, 1973; Jones and Lee, 1979). Where phosphorous is found to be growth-limiting, even small additions may result in dramatic plant growth stimulation. ?

lack of

Increased productivity from nutrient input eventually leads to dissolved oxygen depletions in the deep waters of a pond. Since oxygen is essential for certain organisms living in those depths, the oxygen depletion can have severe ecological impacts. Substantial dissolved oxygen depletions have been observed in the deep water of Gull, Round (West), Great (Truro), and Ryder Ponds, and to a lesser extent in Duck Pond (see Appendix G.2) (Soukup, 1977). Dissolved oxygen depletion in these lower zones can be an indicator of cultural eutrophication. The immediate cause of oxygen depletion is an excess of oxidizable organic matter in the deep water and bottom sediments. Generally the source of organic matter is the upper water layers, the well-lighted photosynthetic zones where plant growth is stimulated by nutrient input.

Dissolved oxygen depletion in the lower zones near the bottom of the pond can enhance the recycling of nutrients, of phosphorous in particular. In low oxygen conditions, certain iron compounds tend to release nutrients including phosphorous into the water. Thus, dissolved oxygen depletion may accelerate the recycling rates of nutrients, increasing the availability of those nutrients which then enhances productivity. Higher productivity can result in more organic input into the bottom layers, thus increasing the dissolved oxygen depletion, which then causes more nutrients to be released from the bottom sediments. Thus, this is a self-enhancing, self-perpetuating process and may result in substantial increases in the productivity and in the rate of pond succession.

Algal blooms, one symptom of increased pond productivity, can result in a decrease in transparency, reducing the depth that light penetrates. A decrease in water clarity is important from a swimmer safety and aesthetic point of view, and it is also biologically important. A decrease in light penetration may result in death of bottom dwelling plants (that rely on light for photosynthesis) and even some animals that rely on plant food and oxygen produced by the plants. This results in an increase in material for decay, which requires oxygen, and further depletes the dissolved oxygen near the bottom. The related decrease in ultraviolet light (that are harmful to bacteria) could also cause an increase in bacterial growth (Ortiz, 1978). Bacterial survival can also be enhanced by excess nutrients available in the water.

Both current and possible sources of nutrients to pond water have been identified and discussed in previous studies (Soukup, 1977; Magnuson, 1973; Cape Cod National Seashore Advisory Commission, 1977; CCPEDC, 1978a). Table XIII lists the major naturally-occurring and human-related nutrient sources that have been implicated for the ponds of Cape Cod National Seashore.

The most probable source of large amounts of nutrients is groundwater, enriched either from septic systems, cesspools, landfill septage disposal sites; but domestic or wild animals and human recreational activities may be more direct sources. Nutrients in residential septic systems may be dramatically increased by the use of phosphate-based detergents (Vollenweider, 1968). In the porous soils of Cape Cod, groundwater flow may be rapid enough to decrease the sorption of nutrients, since even properly operating septic systems do not remove nitrates and phosphates (Magnuson, 1973). Thus, the pattern and rate of groundwater flow as well as the soil type around each pond determines the impact of nonpoint pollution discharges such as septic systems. The National Park Service is currently engaged in a research project to determine groundwater flow around Gull Pond.

Heavy recreational use of certain ponds may be another source of nutrients. Over 1000 bathers may visit one kettle pond during the peak of the summer season. Public restroom facilities are available at only two ponds within the Seashore, so undoubtedly human wastes are being added directly to the other ponds or indirectly along the shoreline.

Table XIII Sources of Water Quality Problems in the Freshwater Kettle Ponds of Outer Cape Cod

Water Quality Proglems	Natural Sources	Human-related Sources
Nutrient Input	Groundwater transport of soil leachate	Groundwater transport of leachate from septic systems
	Rainfall	Groundwater transport of landfill leachate (especially from septage disposal sites)
	Animal and plant debris (conifer needles, deciduous leaves, pollen or animal wastes, gull population wastes,** herring population***)	Use of phosphate detergents in or adjacent to ponds
		Fertilizer use on land adjacent to or upgradient from ponds
	Wind transport (includes salt spray)	Nutrients absorbed on body surface of swimmers (especially if previously in ocean)
	Recycling from bottom sediments during lake turnover or from wind turbulence	Recycling of bottom sediments from recreational use. Human wastes from recreational swimmers
	Release from bottom sediments under low oxygen conditions	Domestic animal wastes
Sediment	Wind turbulence reworking of bottom sediments	Disturbance of bottom sediments from swimmers activity; disturbances of shallow sediments and thermal stratification by motor boats
	Shoreline Erosion	Erosion of banks from human foot or vehicular traffic
	Wind transport	Disturbance of vegetation which holds the soil and dissolved nutrients
		Construction near ponds
Bacteria contamination	Naturally occurring populations	Humans and animals in or adjacent to ponds
		Septic systems
Chemical contamination	Groundwater transport of soil leachate (iron etc)	Groundwater transport from certain land uses (dumps, landfills, gasoli and chemical storage, salt storage,
		Acid rain

**NOTE:
The gull population has increased by a factor of ten over the last few decades, partly due to human influences (Drury an Kadlec, 1

***A percentage of spawning adult herring die in the ponds and thus are nutrient sources.

Sediments and interstitial waters are a repository for nutrients removed from the water (from dying, sinking plankton or other dead organic matter), so resuspension of bottom sediments may also enhance nutrient recycling (even though the sediment particles may be in suspension for only a short period of time). Sediments can be resuspended either by swimmer activity or wind-induced turbulence. Both would have the greatest impact on shallow-water sediments. Resuspension of bottom sediments may increase the nutrients available and thereby increase levels of plant productivity in the pond.

Phosphorous and other nutrients can also be added to the pond from the body surface of swimmers especially if the swimmers have been in the ocean prior to visiting the kettle pond (Soukup, 1977). This source of nutrients is not thought to be a significant problem, however.

Animals, too, can be a source of pond nutrients. In response to this problem as well as to the possible bacterial contamination, Truro and Wellfleet have town rules against allowing dogs and horses in the ponds. However, wild animals may also add nutrients (Geldrich and Kenner, 1969; Fennel et al., 1974). In particular, large numbers of gulls frequent the ponds and are a probable nutrient source. Previous studies on Canada geese indicate substantial nutrient addition from large numbers of birds (Manny, et al., 1975). The National Park Service is currently studying the possible nutrient input to Gull Pond from the gull population (Portnoy, and Soukup, 1980, unpublished). Also a significant percentage of spawning adult herring·die in the ponds and thus are also a source of nutrients, the significance of which has not been evaluated.

Increasing the rate of sediment input can enhance the rate of filling of the pond basin and may reduce water transparencies. The primary source of this sediment is from the banks of ponds, many of which have very steep slopes. Foot or vehicular traffic can substantially increase erosion of the slopes surrounding the ponds directly or indirectly by destroying the vegetation that holds the soil on the steep slopes. There may also be aerial transport of sediment especially if there are large areas of construction or areas denuded of vegetation in the vicinity of the ponds (see TableXIII). Addition of sediments to the pond may decrease water clarity temporarily. Since most sediment on the Cape consists of coarse-grained sands, it is likely that such particles would remain suspended in the water column for only short periods of time, thus, the water transparencies would not be substantially reduced. However, soil nutrients may accompany eroded surface soils and thus aggravate the excess nutrient problem.

In 1974, there was a high incidence of ear and throat infections in the lower Cape area. Local physicians suspected that the infections were related to swimming in the ponds, and bacteria present in recreational waters were implicated as a possible mechanism for disease transmission by body contact. However, since many infections transmitted by swimming are also transferred by other menas, it is difficult to clearly prove a relationship between swimming and infections. The type of bacteria,

the levels of contamination and the incidence of the particular infection are significant determinants of the amount of public health risk. A preliminary study was done in 1974 for the National Park Service (Doolittle, 1974). More intensive bacteriological studies on several ponds were conducted in 1975 and 1976 (Ortiz, 1976; Ortiz et al., 1978). The researchers did isolate several human pathogens; however, comparison of the bacterial concentrations in the ponds with the standards for recreational waters showed that the bacterial level in the ponds were generally below the standards (see Appendix G.4.). However, there were a few days throughout the two summer sampling periods when the standards (with respect to fecal coliform fecal <u>Streptococcus</u>, and <u>Staphylococcus aureus</u>) were exceeded in some of the ponds (Ortiz, et al., 1978) (see Appendix G.4.).

Table XIIIlists several possible sources of bacteria in Cape Cod ponds. Rainwater draining into ponds from upland areas can bring in fecal coliform and fecal <u>Streptococcus</u> from animal feces (Ortiz, 1976a). Research has demonstrated that wildlife can carry human pathogens and can serve as a source of bacteria in the ponds (Geldreich and Kinner, 1969; Fennel et al., 1974). Humans are another source of bacteria to the water. Malfunctioning or inadequate septic systems upgradient from the ponds may be another possible bacterial source although there is evidence that certain types of bacteria and viruses (fecal coliforms and coliphages) may be filtered out in soil under septic systems (Browne, et al., 1979). The degree of health hazards that swimming activities and septic systems contribute depends partly on the incidence of infections in the local communities and, in turn, on the numbers of people swimming in the ponds.

The persistence of pathogens in the ponds depends on the survival, growth, and reproductive rate of the microorganisms. In 1975, hourly sampling during the summer demonstrated a general trend of low bacterial counts in the morning which increased during the day and decreased to normal by evening. This pattern suggests the bacteria levels are associated with recreational use and are either not surviving very long or are being quickly dispersed, or both. Wind-driven turbulence may disperse and thus dilute the concentration of bacteria created by a localized source such as a swimming area. Also, natural communities of minute, free-floating znimals (zooplankton) clean the water by filtering and eating small particles including bacteria. Even so, increased nutrient availability, increased temperatures and reduced water clarity, all associated with cultural eutrophication, may improve the environmental conditions for bacteria and thus enhance their survival.

Another pond water quality problem, chemical contamination, has not yet been observed in the Seashore ponds, but is certainly a potential threat. Several possible chemical contamination sources have been outlined and discussed previously (CCPEDC, 1978a); Table XIII gives a summary. The sources are primarily associated with storage facilities (gasoline, salt, pesticides, herbicides, etc.) or various types of land uses (landfills, highways, etc.) that would contaminate the pond through groundwater seepage or surface runoff. Another recently identified source of chemical pollution is from cesspool and septic system cleaners. Many are organic solvents that are toxic and potentially cancer-causing. When

used to clean cesspools, these chemicals enter the groundwater and then may enter the ponds. Use of fertilizers, herbicides or insecticides in a pond's watershed are also potential chemical contaminants. Runoff from roads and highways may contain a variety of organic substances such as oil and gas but also inorganics such as sodium and chloride from road salting programs during the winter. Atmospheric pollution inpacts from nearby urbanized areas within the Cape's airshed may be felt directly or in the form of acid rain (see Section IV.B.7.). The Cape ponds are particularly vulnerable to impacts from acid rain because of the low buffering capacity of the water.

C) Background Information for Management

Jurisdiction of the ponds in Massachusetts basically depends on whether the pond is less or greater than ten acres.* By the Colonial Ordinance of 1641 as amended in 1647, which remains the law of the Commonwealth today, all ponds greater than ten acres are classified as Great Ponds (Frankel, 1969). Ownership of the beds and water of these Great Ponds and full jurisdiction to regulate the use of the pond, rests with the Commonwealth of Massachusetts. All Great Ponds are open to the public (with certain restrictions) for fishing, fowling, boating, bathing and skating or riding on the ice, regardless of the wishes of those who own shoreline property. However, it is not required by State law that Great Ponds under 20 acres be open to fishing. Owners of the shoreline property may use the ponds, as may other members of the public, but they have no proprietary rights over the pond bed or waters. The property owner, including the National Park Service, may not close, regulate or restrict public access to a Great Pond <u>under normal circumstances</u>; and any land that is not "improved, enclosed or cultivated" may be crossed on foot by members of the public in order to reach Great Pond providing there is no alternative public public access to the pond (Regional Solicitor, DOI, written comm., 25 January 1977 and 31 March 1977).

In 1962, in the process of creating the National Seashore, title to the beds of Great Ponds in Provincetown and Truro was given to the United States. (Title to the beds of Great Ponds in Wellfleet was not transferred.) The National Park Service thus has jurisdiction over the beds of the Great Ponds in Truro and Provincetown. However, the National Park Service, even as owner of the pond bed, cannot regulate use of the waters of a Great Pond in Truro or Provincetown under normal circumstances; the provisions of the Colonial Ordinance of 1647, still prevail.

*This discussion of the legal jurisdiction of ponds is taken primarily from the Pond Management Study, Cape Cod National Seashore Advisory Commission Pond Subcommittee, 1977.

The regulation of activities within Great Ponds is primarily the responsibility of the Commonwealth. However, there is an agreement whereby the state can delegate the regulatory authority to the local towns (Mass. G.L. Chapter 88, section 45). Both Truro and Wellfleet have enacted rules and regulations concerning pond activities that are enforced by the local police and National Park Service rangers.

The laws for surface waters of Massachusetts follow the Common Law doctrine of riparian rights and grant water rights according to land ownership contiguous to the water body. Consequently, for ponds less than ten acres, the jurisdiction for management belongs to the owners of the land around the pond. Where there is divided ownership of the shoreline property, ownership of the pond bed extends to the center of the pond in a triangular shape ("pie slice") with the shore frontage as the base. The owners of small ponds have jurisdiction over their use, subject to the rights of other shoreline owners to use and enjoy their part of the pond bed.

Of the 20 named ponds within the Seashore, 11 are over ten acres and are Great Ponds. The acreage, and the owners of the shoreline of these ponds are listed in Table XIV. The National Park Service owns the land around three of the ponds within the Seashore that are less than ten acres (Round (West) and Snow Ponds in Truro, and Spectacle Pond in Wellfleet) and therefore has exclusive jurisdiction over these three ponds.

Shoreline property owners regulate the activities within ponds less than ten acres as well as land use and activities along the ponds edge. The land activities on the shore of Great Ponds is also controlled by the property owners, except that public access of Great Ponds is guaranteed by law (Colonial Ordinance 1647) that has been upheld in subsequent court cases (Cape Cod National Seashore Advisory Commission, 1977). Ultimately, the Property Clause of the U.S. Constitution may also provide a means for protecting the resource if certain activities were found to disturb the pond water resources to the extent that the purpose of the National Park were disrupted (Regional Solicitor, DOI, written comm., 31 March 1977).

The National Park Service management policies and the Cape Cod National Seashore water resources management objectives (see Section II.A. and B.), for the ponds of Cape Cod National Seashore are long-term preservation of the natural high quality resource, and secondarily, management of compatible recreational use. These objectives are similar to the goals of the Cape Cod 208 Water Quality Management Plan (CCPEDC, 1978a and 1978b) and the Massachusetts CZM plan.

D) Alternatives for Management

1. No additional management action.

This alternative would maintain current management actions by the National Park Service but would not initiate any additional pond management action.

Table XIV

Size and Shoreline Ownership for Kettle Ponds within Cape Cod National Seashore. (Abbreviation for Truro (T) and Wellfleet (W)).

GREAT PONDS

POND	ACREAGE	SHORELINE OWNERS
Great (T)	17.0	Town of Truro, NPS, 8 private owners
Ryder (T)	20.5	NPS, 7 private owners
Horseleech (T)	24.7	NPS, 4 private owners
Slough (T)	29.3	NPS, 8 private owners
Higgins (W)	28.0	NPS, Town of Wellfleet, 7 private owners
Gull (W)	106.0	NPS, Town of Wellfleet, 15 private owners
Long (W)	37.0	NPS, Town of Wellfleet, 18 private owners
Great (W)	44.0	NPS, Town of Wellfleet, 6 private owners
Duck (W)	20.0	NPS, 3 private owners
Dyer (W)	11.8	NPS, 3 private owners

PONDS LESS THAN 10 ACRES

Round (West; T)	4.0	NPS
Round (East; T)	8.0	NPS, 1 private owner
Snow (T)	8.0	NPS
Williams (W)	910	NPS, 6 private owners
Kinnacum (W)	6.4	NPS, 1 private owner
Spectacle (W)	2.0	NPS
Northeast (W)	2.4	NPS, 1 private owner
Turtle (W)	3.9	NPS, 1 private owner
Southeast (W)	2.7	NPS, 2 private owners

Park rangers visit pond areas to advise visitors of town pond rules, and to provide information to park visitors on pond management problems. The Park Service coordinates studies to evaluate pond water problems from both a scientific and planning perspective. The National Park Service has ongoing nutrient level studies in some kettle ponds.

Impact

There are indications water quality in certain ponds is declining with existing management actions (see previous section B). This suggests additional management is required to stop or slow the deterioration of pond water quality. Without initiation of additional pond management, there will be long term and possibly irretrievable damage to resources. Reclamation efforts often prove to be more costly and less effective than preventive management.

2. National Park Service Pond Specific Management Plans

This alternative is an implementation of the recommendations of the Freshwater Pond Management Report by the Subcommittee of the Cape Cod National Seashore Advisory Commission (1977). The committee recommended that management be developed on a pond-by-pond basis. Each pond plan would address problems specific to the pond ~~to the pond~~ but would include sections on shoreline ownership, public access routes, both for trails and roads, erosion control, nutrient input, public restroom facilities, adjacent land use, water level and water quality monitoring, scientific research, enforcement of pond rules, and public information program. A priority list of ponds would be developed to determine the sequence of pond plan preparation.

Impacts

This alternative would primarily involve management of the National Park Service facilities and activities on National Park Service land. There are three ponds less then ten acres where the Park Service owns the entire shoreline. The Park Service shares jurisdiction of all other ponds within the Seashore (see Table XIV).

Direct management actions by the National Park Service alone would undoubtedly mitigate certain problems in the ponds. However, some sources of pond problems (see Table XIII) lie beyond National Park Service jurisdiction and can not be addressed in this alternative except perhaps through the public information program section of the pond plan.

The overall severity of pond problems would be reduced, the level of reduction is difficult to predict but it is possible that pond deterioration would continue in some instances due to sources beyond National Park Service jurisdiction. Thus there may still be irretrievable loss of valuable resources.

There would also be a cost in personnel time necessary for the preparation and implementation of pond management plans. Certain management actions necessary to protect pond water quality may also create inconvenience to recreational users.

3. National Park Service Cooperative Pond-Specific Management Plans

This alternative would be in addition to the pond management planning in Alternative #2, and also involves the preparation of pond-specific management plans. However, this alternative would involve formation of individual pond management committees during the formulation and implementation of each pond-specific plan. Committee membership would include National Park Service staff, pond shoreline owners (including Towns with beach areas), and (on Great Ponds) a representative from the State. (See Alternative #2 for suggested plan content.)

Impacts

This alternative allows pond-specific problems to be addressed by involving all parties with interest and influence on the pond. An increased awareness of pond management problems would result that would facilitate the treatment of sources of pond problems in a comprehensive manner.

This cooperative approach requires organization and coordination of several people. There are personnel costs, and the time required to develop a plan for each pond may be lengthened (over the time required in Alternative #2). Cooperative comprehensive management programs, if successfully prepared and implemented, could address most known sources of pond problems and thus would lessen the probability of irretrievable resource losses.

As in Alternative #2, certain management actions necessary to protect pond water quality may create inconvenience to recreational users and pond shoreline owners. Mitigation measures for this inconvenience will be included in the pond management plan.

E) Proposed Research

Continuation of present pond water quality research.

4. Management of the Gull Pond Sluiceway

A) Problem Statement

In the 1800s, the Wellfleet townspeople dug and stabilized (with sandbags, or wood dikes) a sluiceway between Gull and Higgins Ponds in an effort to give the herring additional spawning area in Gull Pond and thus improve the herring run. Since the Seashore was established, the Park Service has been maintaining an open sluiceway by periodic digging or dredging ~~of~~ a small channel and reinforcing the sides with sandbags. Without this maintenance excavation, the sluiceway would fill in with sand due to the natural pond shoreline processes and the recreational use of the area. The surface water flow between the two ponds would be obstructed by the sand, although groundwater flow would still connect the two ponds. Without the flow of surface water through the sluiceway, the adults of two species of herring (alewife and blue-back herring) would no longer be able to enter Gull Pond to spawn in the spring. ~~which~~ the Massachusetts Division of Fisheries and Game annually stocks with to leave the pond in late summer and fall. Gull Pond

Maintenance of the sluiceway is direct manipulation of the environment in order to retard a natural process. In addition, the excavation process and the sluiceway both may have environmental impacts. Consequently, during the past several years, the consistency of this management with the Park Service management policies for Cape Cod National Seashore has come into question.

B) Resource Description and Problem History

Gull Pond, Higgins Pond and Williams Pond were once part of one large lake basin; they are now separate ponds as a result of sand deposition processes characteristic of natural shorelines (Oldale, 1968). Over a long period of time, wind-induced waves and currents remove shoreline irregularities, sort out sediments and re-deposit sand in protected coves. Such deposits can form a continuous connection between opposite shores and gradually close narrow sections of a lake basin. One such deposit has been formed at Gull Pond, effectively separating Gull from Higgins Pond. Under natural conditions, water exchange in Gull Pond would be only by groundwater seepage in and out of the pond basin in accordance with groundwater flow patterns in the area.

In the previous century, in an effort to improve the run of herring up the Herring River, local townspeople dug and stabilized a narrow, shallow sluiceway, connecting Herring and Gull Pond and allowing herring to reach Gull Pond. At times, the Higgins to Gull Pond sluiceway has been lined with wood and with cement-filled bags; presently there remains only traces of these structures. Without excavation, the sluiceway would close completely due to the natural shoreline processes as well as the recreational use of the area. Erosion of the shoreline from swimmers, sunbathers and fishermen who use the area causes sand to slide into the channel. Since the Seashore

was established, the Park Service has been maintaining the historically open sluiceway by periodic digging or dredging of a small channel and reinforcing the sides with sandbags. Depending on the methods used, the excavation does have some environmental impacts on the immediate area.

There are reportedly two herring species that ascend the Herring River to spawn, alewife *(Alosa pseudoharengus)* and blue-back herring *(A. aestivalis)*. These species are very similar in appearance, but differ somewhat in the time of spawning. The blue-back herring, also known elsewhere as the summer herring (French common name: alose d'ete), ascends the freshwater stream later in the season than the alewife. Each spring (March or April) these anadromous fish begin their spawning run from the ocean into streams and ponds of the Atlantic Coast from South Carolina to Newfoundland. Great numbers of alewives migrate into large rivers such as the St. Johns, the Connecticut and the Potomac, but fish by the thousands also enter much smaller brooks and streams, such as Herring River. Young herring are "imprinted" with olfactory cues which enable them to find their natal stream later in life at spawning time (Thunberg, 1971).

The influx of these fish into relatively small freshwater systems may have a considerable impact upon pre-established food chains and nutrient cycles. Adult fish may remain from a few days to many weeks on the spawning grounds; mortality of adult fish on the spawning grounds is high, 39-57% (Durbin et al., 1979). Young alewives spend part or all of their first summer in the nursery area and then migrate to sea. Because most of their growth and nutrient uptake occurs at sea, these fish represent a significant nutrient source to ponds (through shedding eggs and sperm, excretions and the carcasses of dead spawners). In ground-water-fed lakes, which do not have large amounts of water flowing in and out, such nutrient additions may be significant.

It is also well-established that the young of-the-year herring can effect other changes in lakes. Young alewife feed primarily on zooplankton -- the small animals which feed directly upon the phytoplankton (microscopic, free-floating plants). By reducing the concentration of zooplankton in the surface waters, young herring indirectly cause a larger standing population of algae. This algal density may be one factor in the decreased water clarity evident in Gull Pond. Such a change may, in turn, contribute to the dissolved oxygen deficit observed at the bottom of Gull Pond by reducing the level of light penetration at these depths. (See Section IV.B.3. Management of the Freshwater Kettle Ponds.) This change may eventually affect the trout fishery in Gull Pond since trout also feed on zooplankton.

C) Background Information for Management

The fishery at Gull Pond is managed by the Commonwealth of Massachusetts, Division of Fisheries and Game under the terms of a Memorandum of Understanding signed with the National Park Service

on December 20, 1968. This agreement recognizes that the management of fish (and wildlife) must be a cooperative endeavor. In many national parks where hunting and fishing are permitted, as on Cape Cod, the management of harvesting fish and wildlife populations is the responsibility of the state or towns. Generally, the Park Service is responsible for habitat management and in carrying out this responsibility, may designate zones or establish periods for hunting and fishing in consultation with the state or town. The state or towns are responsible for regulating the hunting and fishing activities; the park may share responsibility for enforcement.

D) Alternatives for Management

1. No additional management action.

This alternative would allow natural processes to proceed without hindrance and would not maintain an open channel.

Impacts

The natural deposition of sand along the shoreline would soon close the sluiceway, initially at the exit to the Gull Pond and the entrance to Higgins Pond. Foot traffic from recreational use would eventually fill in the length of the sluiceway and probably maintain an area of barren sand. The area would be more natural in appearance and the presence of "spoil banks" from dredging would be increasingly less noticeable.

The entrance of herring into Gull Pond would terminate. The herring breeding which now occurs in Gull Pond, that could not be accommodated in Herring and Higgins Ponds, would be lost to the offshore marine fishery and to local herring fishing interests. However, an estimate of this loss is difficult. The contribution of small herring to the diet of other organisms in Gull Pond including certain game fish species, would also be lost. Since young herring remain in surface waters, and trout largely restrict themselves to cooler deep water, the importance of this impact to the trout fishery may be minimal.

A positive impact would be a reduction in the nutrient loading of Gull Pond. Gull Pond has higher phosphorus, nitrogen, and chlorophyll a concentrations than most of the ponds within the Seashore. Studies are presently ongoing to determine the sources of these excess nutrients. That portion of adult herring which die after spawning are a contribution to the nutrient budgets of Gull Pond. However, the relative significance of this source among other possible sources is yet unknown. Early (and tentative) indications of studies on the hydrology of Gull Pond are that the volume of water which seeps into and out of Gull Pond is small. Gull Pond seems to be on a hydrologic divide where groundwater gradients are very slight so that water movement into and out of the pond is not great. Thus any extra nutrients may tend to accumulate and have greater impact than otherwise expected.

Exclusion of juvenile herring from Gull Pond may also result in recovery of the larger zooplankton species. These animals feed on algae so this would reduce the standing algal population and improve water clarity. Greater clarity might lessen the dissolved oxygen deficit in the lower strata of the lake which are isolated from atmospheric oxygen due to water temperature differences.

Preferred Alternative #2. Maintain an open sluiceway.

This alternative requires maintenance digging or dredging by the Park Service at least in spring and late summer.*

Impacts

Maintaining an open channel would provide access for herring to Gull Pond. This alternative would support the existence of a herring spawning area on the Massachusetts coast at a time when other spawning areas are already lost or being threatened (Clayton, Massachusetts CZM office, pers.comm., 1979). The herring fishery in Gull Pond, although not part of the natural Gull Pond system has existed since the 1800s after construction of the first sluiceway.

The environmental impacts to the local area from channel excavation would vary with the excavation method chosen. Mitigation measures for certain environmental impacts and visual intrusion can be taken into consideration during selection of the excavation method.

E) Proposed Research

No additional research is proposed. However, current nutrient input and groundwater flow research will continue.

*If this alternative is chosen, then separate environmental compliance procedures will be prepared during selection of the method for maintaining the sluiceway.

5. Management of Pilgrim Lake

A) Problem Statement

Pilgrim Lake was originally a bay called East Harbor. This harbor was gradually separated from Cape Cod Bay by a northward accreting sand spit. Final closure of the bay occurred in 1868 with construction of a dike along the spit reinforced later with a road and railroad. Since that time Pilgrim Lake has become brackish and eutrophic. The eutrophic condition of the lake is probably due to a number of natural and human factors such as the shallow depth of the lake (increased by migrating dune sand), stirring of lake by coastal winds, nutrient and bacterial input (from gulls and possibly seepage of groundwater rich with septic system effluent), and saltwater influx (at the weir or tidegates and under the ground surface). There are fairly consistant blue-green algae blooms and periodic outbreaks of midges, small non-biting flies. The lake's surface elevation is apparently a major factor in the lake ecosystem. The principal determinants of lake level are (1) the height of the weir located on the bay side of the lake and operated by the Cape Cod Mosquito Control Project and (2) the opening of the tidegates in the dike operated by the Massachusetts Division of Waterways.

B) Resource Description

Pilgrim Lake was originally a bay called East Harbor protected from the Cape Cod Bay by a sand spit (USACE, 1979). In 1868 ~~1968,~~ a dike (with tidegates) for a roadway was built across the inlet to provide passage to Provincetown. In 1873, a railroad bed was constructed on the dike also (Mozgala, 1974). In 1958, in response to concern for mosquito control, a weir (a water-level control structure), was installed above the dike at the eastern end of the lake (Redfield and Emery, 1976).

Before the dike was built, East Harbor was filled with seawater from Cape Cod Bay with every high tide and nearly emptied at each low tide. The salinity was 30 parts per thousand (ppt) and there was probably salt marsh around the bay but certainly on the eastern end (an area still known as Salt Meadow). After the dike and weir were built, the enclosed water, now called Pilgrim Lake became brackish (see Figures 11 and 12 for location of the lake). In 1979, the salinity was between 4 and 5 ppt (Portnoy, NPS, 1978, unpublished data). There are periodic measurements of the elevation of the lake surface, the depth of the lake and some water quality parameters since 1948 (Mozgala, 1974; Redfield and Emery, 1976).

The lake level and the salinity vary through the year in response to precipitation and to operation of the tidegates and the weir. The significance of the elevation of the surface of the lake to the ecological community in the lake was demonstrated in 1968 and 1969 when the lake surface level changed in response to a change in the weir height.

During those two years there were massive outbreaks of midges, small non-biting flies whose larvae live in the lake bottom sediments. Research has suggested these midge outbreaks were associated with changes in the water level and a subsequent sequence of ecological events (Mozgala, 1974). The increased salinity from the entry of seawater into Pilgrim Lake may have killed the phytoplankton and pondweeds. The decomposition of this extra organic matter and low aeration during calm weather, may have depleted the oxygen which subsequently killed the fish. It is the absence of the carp, the main predators of midge larvae, that apparently led to the outbreaks of midges (Mozgala, 1974).

The lake may be getting shallower from the addition of sand from migrating dunes and accumulation of soft sediments. In 1948, the maximum depth was 7 feet (2.1 meters), mean depth was 4 feet (1.2 meters) (Mozgala, 1974). In 1969, the depths to the soft bottom average 2.5 feet, depths to hard sand, though were greater (Redfield and Emery, 1976). The soft bottom is due to a thick layer of organic matter mixed with silt. The thickness of this layer varies from more than eight feet in the western end of the lake to less than six inches over most of the bottom (Redfield and Emery, 1976). The closure of the inlet to tidal currents apparently led to the accumulation of the layer of detritus. Bacterial decomposition in the bottom sediments can lead to oxygen depletions in the sediments and subsequent production of hydrogen sulfide, that creates unpleasant odors. Due to the shallowness of the lake, the temperature is generally close to the air temperature, and stratification usually does not occur. Mixing by wind generally keeps the oxygen content fairly high and the lake usually supports a population of fish (perch, alewife and carp).

The winds over the surface of the lake, stir the soft bottom sediments, suspend the fine particles, decrease the water clarity, and probably add nutrients to the water. The water transparency (10-75 cm in 1971 and 1972) is further reduced by the large number of phytoplankton, primarily blue-green algae. Blue-green algal blooms occur in the spring, summer and fall giving the lake its characteristic green color.

High values of total phosphorous, and ammonia-nitrogen have been recorded (Mozgala, 1974; Redfield and Emery, 1976; CCPEDC, 1978a). The source of these high values has not been determined but may be from a variety of factors including the gull population, septic systems, and leaching from old salt marsh sediments (Mozgala, 1974).

The marsh areas around Pilgrim Lake are dominated by either cattail or reeds. There is a network of mosquito control ditches in these marshes maintained by the Cape Cod Mosquito Control Project. There may be impacts on the marsh system from the ditching that adversely affect vegetation, animal communities and patterns of water flow in the area around Pilgrim Lake.

C) Background Information for Management

The Seashore has jurisdiction over the pond beds of those lakes adjacent to its property holdings in Provincetown and Truro. Along Pilgrim Lake, most of the land is part of the Seashore, thus, management of these areas is largely a park responsibility. However, Pilgrim Lake is a Great Pond, so the Commonwealth of Massachusetts is involved in management of the lake. In addition, the Massachusetts Divisions of Fisheries and Game and Marine Fisheries are responsible for management of the lake fisheries, and the Cape Cod Mosquito Control Project and the Massachusetts Division of Waterways (in DEQE) have responsibility for the operation and maintenance of the weir and the tidegates.

National Park Service Policies seek to minimize interference with natural systems and to restore natural systems whenever past impacts have occurred. Control of non-biting insects that pose no problem to public health is contrary to this endeavor. In the past, the National Park Service responded to the midge outbreaks with pesticide applications (Mozgala, 1974). However, subsequent policy changes make this response, in general, inappropriate. As a part of management policy, the Department of Interior seeks to reduce pesticide use, and exclude their use when water quality will be degraded or hazards exist that will unnecessarily threaten "fish, wildlife, their food chains or other components of the natural environment" (Soukup, 1978; DOI, 1977).

Included in this policy is a ban against large-scale, nonspecific application of any pesticide, and a commitment to a general reduction in pesticide use. In general, chemical pesticides of any type will be used only where feasible alternatives are not available or acceptable (National Park Service, 1978). Since midges are a nonbiting insect and constitute only a short-term nuisance and discomfort, but no health hazard, pesticide use is generally not warranted under current policy.

D) Alternatives for Management

1. No additional management action.

Under this alternative the Seashore would initiate no management actions for Pilgrim Lake.

<u>Impacts</u>

With no additional management by the Park Service, the present poor water quality conditions in Pilgrim Lake will probably continue and may degrade even further.

The elevation of the lake surface and the resulting salinity is controlled by the weir height and the tide gates, both managed by agencies other than the Park Service. Consequently, management decisions made by

other agencies may have impacts on the condition of the lake. Uncoordinated actions by several agencies may lead to future lake management problems.

Preferred Alternative #2. Develop a Management Plan and Cooperative Management Agreement for Pilgrim Lake

Under this alternative, the Park Service would assess the current status of Pilgrim Lake and develop specific management actions to improve the present conditions. This plan would be developed concurrently with additional water quality research (see Section E). Due to the numerous agencies with management responsibilities, a cooperative agreement on Pilgrim Lake with other agencies including the Cape Cod Mosquito Control Project and Division of Waterways, would be an important part of a management program.

Impacts

Examination of the present conditions in Pilgrim Lake during the preparation of a Management Plan may identify specific actions that can be taken by the Park Service or in cooperation with other agencies. Closer coordination among agencies with management responsibilities would lead to improved management and thus enhanced water quality in Pilgrim Lake. There may be personnel costs among the various agencies including the Park Service, involved in the preparation of the Management Plan.

E) Proposed Research

An evaluation of water quality in Pilgrim Lake with particular emphasis on patterns and variation in nutrient levels and salinity. Investigate the hydrology of the lake, i.e., the source and the quality of water entering the lake.

6. Management of the Water and Marsh Areas Upstream from from the Herring River Dike

A) Problem Statement

In 1974, after many years of gradual deterioration, the Herring River dike (originally built in 1908) was repaired by the Massachusetts Division of Waterways at the request of the Wellfleet Selectmen. Prior to reconstruction, the Wellfleet Conservation Commission issued an order of conditions under the Wetlands Protection Act, which required that the dike would not interfer with the tidal saltwater flow and the passage of alewives. However, after the dike was repaired, the water level behind the dike dropped. The decreased tidal flushing of the upstream marsh areas has altered the estuarine environment and changed the associated biological community. In addition, due to the restriction of tidal flow, sand has begun filling in behind the dike and silting in the marsh.

To date, the Wellfleet Selectmen have refused to raise the water level, reportedly because there are two houses located up river from the dike in the 100-year floodplain that may be threatened by flooding if the tide gates are opened further. In January 1979, the Wellfleet Herring River Dike Committee submitted a plan for the operation of the dike. However, the plan has not been accepted by the Selectmen. This issue is periodically reopened but has remained unresolved for a number of years since dike reconstruction.

In the marsh areas behind the dike, there is also an active program of ditching by the Cape Cod Mosquito Control Project that may have adverse direct and indirect impacts on the marsh ecosystem.

B) Resource Description and Problem History

The Herring River, 5 kilometers (3.8 miles) in length, begins as a small stream about one meter wide draining Herring Pond which stands at an elevation of 1.8 meters (6 feet).* Herring Pond receives water from three other nearby kettle hole ponds - Williams, Higgins, and Gull. These ponds and groundwater flow provide a substantial and nearly continuous source of water for the river in most years. The headwater stream flowing out of Herring Pond has a channel about one meter deep in the glacial sediments.

Even though the river has a very gradual gradient from the source to the mouth, about 0.36 meters per kilometer (1.6 feet per mile), there is enough flow to prevent freezing during the winter. The greatest flow rate is near the Bound Brook Island-Merrick Island area. The flow rate increases from Herring Pond to Bound Brook Island road (0.08 meters per second near Herring Pond, 0.11 meters per second at Old Kings Highway, 0.125 meters per second at Route 6 and 0.20 meters per second at Bound Brook Island) and then decreases (0.063 meters per second) just as it enters the estuary where the flow rates are dependent on the tidal stage. Since there is no steep gradient change, it seems that this flow rate pattern is due to increased water volume in the river channel.

The water quality is determined by the river sources which are the groundwater and the kettle ponds, so the water is clear and of high quality (see Appendix H).

In 1908, according to a plan developed by Whitman and Howard, a dike was constructed at the mouth of the Herring River to regulate and reduce the tidal flow into the marsh in order to control mosquitos and convert "useless" salt marsh into freshwater marsh (Sterling, 1976). The

* A more detailed description of the Herring River is in Godfrey, *et al.*, 1977.

dike did reduce the tidal flow and the salt marsh community was replaced by a freshwater marsh. By 1910, the herring run was diminished, the mosquitos were apparently still a problem, and no agricultural use was made of the freshwater marsh (Sterling, p. 12-13, 1976).

By the late 1960s, due to the gradual deterioration of the old dike valves, the incoming tidal water flowed into the river, and by the early 1970s, salt marsh species began to recolonize the area behind the dike. In the summer of 1974, a baseline study documented the recolonization of the salt marsh vegetation and associated fauna typical of shallow estuarine habitats (such as oysters, ribbed mussels, eelgrass, marine algae, fiddler crabs, menhaden, and bluefish) (Snow, 1974). In 1973, near the mouth of the river, salinities at the dike on a low tide were 13 parts per thousand (ppt) at the dike and 0 ppt about 1.5 kilometers from the dike, while on a flood tide, salinities ranged from 31 ppt at the dike to 4 ppt 1.5 kilometers upstream (Moody, 1974).

In November, 1974, amid controversy generated by the Wellfleet Conservation Commission, some local shellfishermen and other Wellfleet townspeople, the Wellfleet Selectmen decided to rebuild the dike. The Waterways Division (at that time in the Department of Public Works) was asked to rebuild the dike. During the public hearing required by the Massachusetts Wetland Protection Act (Mass. G.L. Chapter 131, section 40), the Conservation Commission added an order of conditions (DNR 77-2) to the permit that required the reconstructed dike would not alter the amount of salt water flowing through the dike and would allow free passage of the alewives through the dike.

However, after the dike was reconstructed in 1974, the water level and the salinity behind the dike dropped. Under threat of a court injunction obtained by several Wellfleet residents, the Waterways Division made some changes in the flood tide gates and improved the passage of both saltwater and alewives (Sterling, 1976). However, the water level still apparently has not been reestablished to the 1973 level. Since reconstruction, there have been differing opinions on the impacts of the dike and the altered water flow (Fiske, Division of Marine Fisheries, written communication, 1979; The Provincetown Advocate, March 13, 1980).

In 1975, representatives from the Town of Wellfleet, the National Park Service, the Association for the Preservation of Cape Cod (APCC) and several state agencies met to establish a monitoring program for the Herring River dike. This program was never instituted.

In 1977, the Wetlands Program of the Massachusetts Department of Environmental Quality Engineering (DEQE), the agency most responsible for enforcing the order of conditions, filed a law suit against the Town of Wellfleet. The State Attorney General's office is responsible for prosecution of this case; however, as of September 1980, the suit is still pending.

The Wellfleet Selectmen have refused to change the position of the tide gates apparently because there are two houses located upstream from the dike in the 100-year floodplain, that experience periodic basement flooding problems allegedly related to the tidal inflow into the mouth of the Herring River. (There is a third house located in the floodplain with no basement and is not subject to similar flooding.)

There is also an active program of ditching for mosquito control in the marshes of the river by the Cape Cod Mosquito Control Project. The ditching may have direct impacts on the vegetation, animal life, topography, and water flow in the marshes as well as indirect impacts by altering natural patterns of groundwater flow.

Current Status

In March 1980, the question of the tide gates on the Herring River dike was reopened again due to continued concern for the low water level behind the dike and the related decrease in shellfish productivity (see The Provincetown Advocate, March 16, 1980; Cape Cod Times, March 16, 1980). The State Attorney General's Office is actively considering this case.

C) Background Information for Management

Figure 24 indicates the land ownership in the vicinity of the Herring River dike. The National Park Service owns a substantial portion of the land area behind the dike that would probably be influenced by increased tidal flushing. In addition, one of the two houses in the 100-year floodplain (Tract 26-4654) currently in private ownership may be subject to acquisition by the Park Service.

The Wetlands Program, DEQE, is responsible for enforcing the order of conditions for the dike. The Division of Waterways, now in DEQE, officially has jurisdiction over the dike, however, the Town of Wellfleet currently has possession of the key to the tide gates.

D) Alternatives for Management

1. No additional management action.

The Park Service would initiate no management program for the Herring River and marsh system.

Impacts

With no management action, silting of marsh behind the dike and modification of the biological, formerly estuarine and salt marsh community behind the dike would continue. It is also possible that continued use of mosquito ditching techniques, originally aimed at salt marsh mosquito species, are effectively draining the upper portions of the now freshwater wetlands, possibly causing irretreivable loss of these valuable areas.

Mosquito Control Project will clarify the need and techniques for mosquito control in the Herring River marshes.

E) Proposed Research

An evaluation of the present wetlands behind the dike and a comparison with the historical extent and type of marsh vegetation. Determine the possible range of impacts on the marsh vegetation and animal life, surface water flow and the groundwater flow that would accompany opening the tide gates further than required in the order of conditions or removing the dike entirely.

Determine the impact on marsh vegetation, animal life and groundwater flow of mosquito control ditches.

Investigate water quality in the Herring River.

7. Assessment and Management of the Impacts of Acid Rain

A) Problem Statement

The resources of the Seashore may be adversely affected by acid rain. The freshwater resources of the Seashore may be particularly vulnerable because of the low buffering capacity (i.e. the acid-neutralizing capacity) of the freshwater and the soil on Cape Cod. The Seashore is located east and downwind of several nearby urban industrial centers such as Boston and Fall River as well as from more distant areas of New York City-Newark, Chicago-Pittsburgh and Cincinnati-Ohio River Valley. Chemical conversion of the sulfur and nitrogen compounds in the air pollution from these urban and industrial centers creates acid rain. Acid rain is known to adversely impact ecological communities, both terrestrial and aquatic.

B) Resource Description and Problem History

Wind-borne pollution containing both nitrogen (NOx) and sulfur (SO_x) compounds, from urban and industrial centers may be transported many miles. These compounds under the influence of oxygen, water and sunlight can chemically convert to sulfuric acid and nitrous and nitric acid, two components of acid rain.

Hydrochloric acid can also be a component to acid rain if the coal that is burned contains chlorine. Other air-borne chemicals, such as toxic heavy metals and organic toxins from urban and industrial sources, also become chemically part of acid rain (Gorham, 1976). Cape Cod is east and downwind from several urban and industrial centers.

Historical data suggest that the acidity of rain and snow in the northeast increased about 1950-1955 (Likens and Bormann, 1974). Since that time,

precipitation in the northeast has been more acid than expected under natural conditions. The annual acidity values for the northeastern U.S. average around pH 4 but values as low as 2.1 have been recorded for individual storms (Likens and Bormann, 1974). Precipitation is significantly more acidic in northeastern U.S. Than anywhere else in the country. Table XV gives some initial data on the pH of rainfall at the Seashore.

Studies on the impacts from acid rain on both terrestrial and aquatic environments have been conducted in recent years in Europe, Canada, and the U.S. (Dvorak et al., 1978). Direct adverse effects on aquatic systems, on vegetation and alteration of the chemical properties of the soil have been observed (Dvorak et al., 1978).

Acidification of ponds and streams from acid rain makes the environment unsuitable for many types of organisms and thus changes the natural community composition (see Dvorak et al., 1978 for references). For example, the increased acidity of lakes in Canada, New York and Scandanavia has reduced or eliminated the populations of many fish species including some of the most desirable game fish. Some lakes in the Adirondack Mountains and in Canada have become entirely devoid of fish in recent years (Beamish and Harvey, 1972; Beamish et al., 1975). The increased acidity may be directly toxic to fish. In addition, the food supply is decreased since the abundance and diversity of plankton are also reduced. The number of young fish surviving to adult has been observed to decrease, which adversely affects the successful reproduction of fish populations (Schofield 1976 cited in Dvorak et al., 1978).

Vegetation can be directly impacted by acid rain since some rain is intercepted by leaves and stems of plants, and plant roots are affected by changes in the soil chemistry. Plants show a variety of effects including decreased growth, poor seed germination, and an increased susceptibility to disease (see Dvorak et al., 1978 for references). The amount of change in the chemistry of the soil is determined to a large extent by the buffering capacity that is low on the Cape due to the non-calcerous soil. Lowering the pH of the soil can result in leaching of the positively charged ions (such as calcium and magnesium) as well as other nutrients from the soil and can cause an increase in the availability of certain metals (such as zinc and aluminum) sometimes to toxic levels (see Dvorak et al., 1978 for references). Increased leaching from the soils can also impact adjacent water resources.

C) Background Information for Management

Cape Cod National Seashore is designated a Class I area under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as amended. This classification allows for the air quality degradation that accompanies well-planned economic growth. The Environmental Protection Agency has the prime responsibility for air quality control in the Commonwealth of Massachusetts; since Massachusetts has not completed a State Implementation Plan. At this time, there are no federal or state regulations governing acid rain, however, a great deal of research is presently being conducted in this area in order to design central strategies.

Table XV The pH of Rainfall at Cape Cod National Seashore

DATE	pH	REMARKS
7/1/79	5.71	
7/5/79	5.13	
7/10/79	4.79	
7/26/79	4.78	Thunder showers
7/30/79	4.69	Light rain
8/4/79	5.02	Hard rain during night and morning
8/6/79	4.7	Hard rain early evening
8/8/79	4.82	Hard rain at night
8/11-12/79	4.97	Heavy rain for 2 days
9/5/79	6.2	Hurricane David; 0.81" in rain 1pm-6pm
9/28/79		Emptied Rain Collec[illegible] = 9.88
10/4/79	5.9	1.05
10/10/79	5.5	
11/3/79	4.9	1.7"
11/19/79	4.3	
11/27/79	4.5	
12/3/79	3.8	Snow
12/10/79	4.2	Heavy rain overnight; fair spell before and after several days
12/13/79	3.90	Heavy rain all day, 5^{o} C
12/17/79	5.10	Brief but heavy rain; 9.5" 3^{o} C
12/26/79	4.55	Steady rain all day (0.3"); 7^{o} C
1/14/80	5.20	Heavy overnight southeaster; 3^{o} C
1/15/80	5.10	N'easter; 1.5"; heavy all day rain; 7^{o} C
2/14/80	5.15	Light snow
2/16/80	4.5	All day rain/snow (0.5")
3/26/80	4.80	Light but all day rain; 0.5"
3/30/80	4.90	Heavy AM rain; 0.7"
4/10/80	4.60	Intermittent but heavy rain
4/15/80	4.95	Heavy 1-hour squall; 0.4"
6/30/80	4.4	Heavy Thunderstorms, 18^{o} C
7/1/80	4.5	Thundershowers, 19^{o} C
7/5/80	4.8	Brief shower after 3 week draught, 0.25"% rain, 23^{o} C
8/11/80	4.2	Steady 0.5" rain; 27^{o} C
8/12/80	4.6	Heavy Thundershowers, 0.8", 27^{o} C

D) Alternatives for Management

At this time, due to the lack of baseline data on the severity of the acid rain problem on Cape Cod, the Park Service is not considering any direct management actions.

E) Proposed Research

Determine the severity of the acid rain problem on the outer Cape and assess the need for management action. Collect baseline data on the chemicsty of precipitation (both wet and dry fallout) from a monitoring station. Collect data and assess the impact of acid rain on the chemistry of surface waters, vegetation, animal life, and soil.

V. Consultation and Coordination with Others

Although this report was prepared by the Office of Scientific Studies in the Regional Office in close cooperation with the staff of Cape Cod Nationsl Seashore, this document is actually a product of many other people's time and effort. In particular, we want to thank the following individuals who supplied information or provided review at various stages of this report:

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VI. Compliance with Existing Laws

The Assessment of Water Resources Management Alternatives is the compliance with the following laws and executive orders. (For further discussion see Section II.C.)

- Coastal Zone Management act of 1972
- Clean Water Act as amended in 1977
- Federal Safe Drinking Water Act of 1974
- National Environmental Policy Act (NEPA)
- Executive Order 11988 Floodplain Management
- Executive Order 11990 Protection of Wetlands

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